# PROCEEDINGS

AND

# TRANSACTIONS

OF THE

# LIVERPOOL BIOLOGICAL SOCIETY.

VOL. XXXII.

SESSION 1917-1918.

*PRICE—TEN SHILLINGS AND SIXPENCE.*

LIVERPOOL:

C. TINLING & CO., LTD., PRINTERS, 53, VICTORIA STREET.

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### I.—Proceedings.



### II.—Transactions.

PROCEEDINGS

OF THE

# LIVERPOOL BIOLOGICAL SOCIETY

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1907—1908 W. T. HAYDON, F.L.S.
1908—1909 Prof. B. MOORE, M.A., D.Sc.
1909—1910 R. NEWSTEAD, M.Sc., F.E.S.
1910—1911 Prof. R. NEWSTEAD, M.Sc., F.R.S.
1911—1912 J. H. O'CONNELL, L.R.C.P.
1912—1913 JAMES JOHNSTONE, D.Sc.
1913—1914 C. J. MACALISTER, M.D., F.R.C.P.
1914—1915 Prof. J. W. W. STEPHENS, M.D., D.P.H.
1915—1916 Prof. ERNEST GLYNN, M.A., M.D.
1916—1917 Prof. J. S. MACDONALD, L.R.C.P., F.R.S.

## SESSION XXXII, 1917-1918.

### President:

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### Vice-Presidents:

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Prof. W. A. HERDMAN, D.Sc., F.R.S.

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### Hon. Librarian:

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DOUGLAS LAURIE, M.A.
W. S. LAVEROCK, M.A., B.Sc.
Prof. R. NEWSTEAD, M.Sc., F.R.S.
Prof. W. RAMSDEN, M.A., D.M.
W. RIMMER TEARE.
EDWIN THOMPSON.

*Representative of Students' Section:*

Miss C. M. JARVIS.

## REPORT of the COUNCIL.

During the Session 1917-18 there have been seven ordinary evening meetings and one field meeting.

The communications made to the Society at the ordinary meetings have been representative of many branches of Biology, and the various exhibitions and demonstrations thereon have been of great interest.

On the invitation of the Council, Dr. William Evans Hoyle, Director of the Welsh National Museum at Cardiff, lectured to the Society, on January 25th, on "Edward Lhuyd, a Welsh Naturalist."

The Library continues to make satisfactory progress, and additional important exchanges have been arranged.

The Treasurer's statement and balance sheet are appended.

The members at present on the roll are as follows :—

| | |
|---|---|
| Ordinary members ... ... ... ... ... | 45 |
| Associate members ... ... ... ... ... | 11 |
| Student members, including Students' Section, about | 30 |
| Total ... ... | 86 |

## SUMMARY of PROCEEDINGS at the MEETINGS.

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The first meeting of the thirty-second session was held at the University, on Friday, October 12th, 1917.

The President-elect (Joseph A. Clubb, D.Sc.) took the chair in the Zoology Theatre.

1. The Report of the Council on the Session 1916-1917 (see "Proceedings," Vol. XXXI, p. viii) was submitted and adopted.
2. The Treasurer's Balance Sheet for the Session 1916-17 (see "Proceedings," Vol. XXXI, p. xvi) was submitted and approved.
3. The following Office-bearers and Council for the ensuing Session were elected :—Vice-Presidents, Prof. Herdman, D.Sc., F.R.S., and Prof. J. S. Macdonald, L.R.C.P., F.R.S.; Hon. Treasurer, W. J. Halls; Hon. Librarian, May Allen, B.A.; Hon. Secretary, Prof. W. A. Herdman, F.R.S.; Council, R. C. Bamber, M.Sc. (Miss), J. W. Cutmore, G. Ellison, W. T. Haydon, F.L.S., Prof. E. Glynn, M.A., M.D., J. Johnstone, D.Sc., Douglas Laurie, M.A., W. S. Laverock, M.A., B.Sc., Prof. R. Newstead, M.Sc., F.R.S., Prof. W. Ramsden, M.A., D.M., W. Rimmer Teare and Edwin Thompson, C.C.
4. Dr. Joseph A. Clubb delivered the Presidential Address on "The Public Museum and Education" (see "Transactions," p. 3). A vote of thanks proposed by Prof. Herdman, seconded by Mr. J. G. Legge, Director of Education, was passed.

The second meeting of the thirty-second session was held at the University, on Friday, November 9th, 1917. The President in the chair.

1. Prof. Herdman submitted the Annual Report on the work of the Liverpool Marine Biology Committee, and gave an address on "Sir John Murray, K.C.B., F.R.S., the Pioneer of Modern Oceanography" (see "Transactions," p. 15).

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The third meeting of the thirty-second session was held at the University, on Friday, December 14th, 1917. The President in the chair.

1. Mr. G. Ellison exhibited a photograph and drawing of a carved stone found near Stenness, in the Orkneys.
2. Dr. Johnstone submitted the Annual Report of the Investigations carried on during 1917, in connection with the Lancashire Sea-Fisheries Committee (see "Transactions," p. 73).

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The fourth meeting of the thirty-second session was held at the University, on Friday, January 11th, 1918. The President in the chair.

1. Mr. G. Ellison exhibited, with remarks, stuffed specimens of the Orkney vole, and of a white variety differing from an albino in having black eyes.
2. Mr. J. W. Cutmore exhibited and discussed a series of birds and mammals having unusual colouring.
3. Prof. Herdman exhibited, with remarks, some rare plankton organisms from the Indian Ocean and the Pacific.
4. Dr. Clubb gave an account of the occurrence of Lepidopterous larvae, and the nest and larvae of a solitary wasp in a gaspipe.
5. Mr. W. S. Laverock exhibited a number of solitary wasps from the Malay Peninsula, along with their nests and food supplies for their young.

The fifth meeting of the thirty-second session was held at the University, on Friday, January 25th, 1918. The President in the chair.

1. On the invitation of the Council, Dr. William Evans Hoyle, Director of the Welsh National Museum at Cardiff, lectured on "Edward Lhuyd, a Welsh Naturalist." Dr. Hoyle traced Lhuyd's connection with Ashmole at the University of Oxford and his important work in connection with the Ashmolean Museum. His work on British star-fishes and in other departments of Natural History was also discussed in a most interesting manner.

A cordial vote of thanks to the lecturer was passed.

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The sixth meeting of the thirty-second session was held at the University, on Friday, March 8th, 1918. The President in the chair.

1. Miss H. M. Duvall, B.Sc., gave an address on "The Bionomics and Economic Importance of the Mites infesting grain and flour."

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The seventh meeting of the thirty-second session was held at the University, on Friday, May 10th, 1918. The President in the chair.

1. Prof. Herdman communicated a series of notes dealing with recent marine biological occurrences at Port Erin.
2. Mr. W. S. Laverock communicated notes on the Beasley collection of triassic fossils, recently acquired for the Free Public Museum.
3. Mr. Douglas Laurie gave a short account of the habits and physiology of *Ligia oceanica.*

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The eighth meeting of the thirty-second session was the Annual Field Meeting, held on Saturday, June 8th, 1918, when Mr. Douglas Laurie acted as leader and conducted the members to various field-ponds and ditches in the neighbourhood of Moreton and Leasowe. At the short business meeting held after tea, on the motion of the President from the chair, Professor W. Ramsden was unanimously elected President for the ensuing session.

## LIST of MEMBERS of the LIVERPOOL BIOLOGICAL SOCIETY.

### *SESSION* 1917-1918.

### A. Ordinary Members.

(Life Members are marked with an asterisk.)

ELECTED.

1908 Abram, Prof. J. Hill, 74, Rodney Street, Liverpool.
1909 *Allen, May, B.A., Hon. Librarian, University, Liverpool.
1913 Beattie, Prof. J. M., M.A., M.D., The University, Liverpool.
1903 Booth, jun., Chas., 30, James Street, Liverpool.
1912 Burfield, S. T., B.A., Zoology Department, University, Liverpool.
1886 Caton, R., M.D., F.R.C.P., Holly Lea, Livingston Drive, Liverpool, S.
1886 Clubb, J. A., D.Sc., President, Free Public Museums, Liverpool.
1916 Dale, Sir Alfred, The University, Liverpool.
1917 Duvall, Miss H. M., B.Sc., Zoology Department, University, Liverpool.
1910 Ellison, George, 52, Serpentine Road, Wallasey.
1902 Glynn, Dr. Ernest, 67, Rodney Street.
1886 Halls, W. J., Hon. Treasurer, 35, Lord Street.
1896 Haydon, W. T., F.L.S., 55, Grey Road, Walton.
1912 Henderson, Dr. Savile, 48, Rodney Street, Liverpool.

1886 Herdman, Prof. W. A., D.Sc., F.R.S., VICE-PRESIDENT, HON. SECRETARY, University, Liverpool.
1893 Herdman, Mrs. W. A., Croxteth Lodge, Ullet Road, Liverpool.
1912 Hobhouse, J. R., 54, Ullet Road, Liverpool.
1902 Holt, Dr. A., Dowsefield, Allerton.
1903 Holt, Richard D., M.P., India Buildings, Liverpool.
1898 Johnstone, James, D.Sc., University, Liverpool.
1896 Laverock, W. S., M.A., B.Sc., Free Public Museums, Liverpool.
1906 Laurie, R. Douglas, M.A., University, Liverpool.
1912 Macalister, C. J., M.D., F.R.C.P., 35, Rodney Street, Liverpool.
1915 Macdonald, Prof. J. S., B.A., F.R.S., VICE-PRESIDENT, The University, Liverpool.
1917 Milton, J. H., F.G.S., Merchant Taylors' School, Great Crosby.
1904 Newstead, Prof. R., M.Sc., F.R.S., University, Liverpool.
1904 O'Connell, Dr. J. H., 38, Heathfield Road, Liverpool.
1913 Pallis, Mark, Tätoi, Aigburth Drive, Liverpool.
1903 Petrie, Sir Charles, 7, Devonshire Road, Liverpool.
1915 Prof. W. Ramsden, University, Liverpool.
1903 Rathbone, H. R., Oakwood, Elmswood Road, Aigburth.
1890 *Rathbone, Miss May, Backwood, Neston.
1910 Riddell, Wm., M.A., Zoology Department, University, Liverpool.
1897 Robinson, H. C., Malay States.
1908 Rock, W. H., 25, Lord Street, Liverpool.
1894 Scott, Andrew, A.L.S., Piel, Barrow-in-Furness.
1908 Share-Jones, J., D.Sc., F.R.C.V.S., University, Liverpool.
1886 Smith, Andrew T., 21, Croxteth Road, Liverpool.
1903 Stapledon, W. C., "Annery," Caldy, West Kirby.
1913 Stephens, Prof. J. W. W., M.D., University, Liverpool.
1903 Thomas, Dr. Thelwall, 84, Rodney Street, Liverpool.

1905 Thompson, Edwin, 25, Sefton Drive, Liverpool.
1889 Thornely, Miss L. R., Hawkshead, Ambleside.
1888 Toll, J. M., 49, Newsham Drive, Liverpool.
1918 Whitley, Edward, Bio-Chemical Laboratory, University.
1891 Wiglesworth, J., M.D., F.R.C.P., Springfield House, Winscombe, Somerset.

## B. Associate Members.

1916 Atkin, Miss D., High School for Girls, Aigburth Vale, Liverpool.
1915 Bamber, Miss, M.Sc., Zoology Department, The University, Liverpool.
1905 Carstairs, Miss, 39, Lilley Road, Fairfield.
1914 Cutmore, J. W., Free Public Museum, Liverpool.
1916 Gleave, Miss E. L., M.Sc., Oulton Secondary School, Clarence Street, Liverpool.
1905 Harrison, Oulton, 3, Montpellier Crescent, New Brighton.
1916 Horsman, Miss Elsie, B.Sc., 17, Hereford Road, Wavertree.
1915 Stafford, Miss C. M. P., B.Sc., 312, Hawthorne Road, Bootle.
1917 Swift, Miss F., B.Sc., Queen Mary High School, Anfield.
1915 Teare, W. Rimmer, 12, Bentley Road, Birkenhead.
1912 Wilson, Mrs. Gordon, High Schools for Girls, Aigburth Vale, Liverpool.

## C. University Students' Section.

*President:* Miss C. M. Jarvis.

*Secretary:* Miss M. Howells.

(Contains about 30 members.)

## D. Honorary Members.

S.A.S., Albert I., Prince de Monaco, 10, Avenue du Trocadéro, Paris.

Bornet, Dr. Edouard, Quai de la Tournelle 27, Paris.

Fritsch, Prof. Anton, Museum, Prague, Bohemia.

Haeckel, Prof. Dr. E., University, Jena.

Hanitsch, R., Ph.D., Raffles Museum, Singapore

# THE LIVERPOOL BIOLOGICAL SOCIETY.

Cr. IN ACCOUNT WITH W. J. HALLS, HON. TREASURER. Dr.

| 1917, Oct. 1st to Sept. 30th, 1918. | £ | s. | d. |
|---|---|---|---|
| By Balance from last Session | 14 | 17 | 7 |
| ,, Subscriptions | 13 | 13 | 0 |
| ,, ,, (in Advance) | 3 | 3 | 0 |
| ,, ,, (in Arrears) | 6 | 6 | 0 |
| ,, Associate Members | 2 | 12 | 6 |
| ,, Subscription paid into Bank | 1 | 1 | 0 |
| ,, Sale of Volumes | 42 | 2 | 5 |
| ,, Interest on Investment | 3 | 13 | 9 |
| ,, Bank Interest | 0 | 6 | 9 |
| | £87 | 16 | 0 |

INVESTMENT :—

£125 4 % Debenture Stock (Commercial Cable Co.) at £70 ................ £87 10 0

| 1917, Oct. 1st to Sept. 30th, 1918. | £ | s. | d. |
|---|---|---|---|
| To Teas | 2 | 8 | 11 |
| ,, Fire Insurance—Society's Library | 2 | 4 | 0 |
| ,, Secretarial Expenses | 1 | 0 | 11 |
| ,, Librarian's Expenses | 2 | 13 | 10 |
| ,, Messrs. Tinling & Co. | 38 | 3 | 0 |
| ,, Postages (Treasurer) | 0 | 0 | 9 |
| ,, Balance in Bank | 35 | 4 | 0 |
| ,, Cash in hand | 6 | 0 | 7 |
| | £87 | 16 | 0 |

*Audited and found correct,*

JOSEPH A. CLUBB.

LIVERPOOL, *September 30th, 1918.*

TRANSACTIONS

OF THE

# LIVERPOOL BIOLOGICAL SOCIETY.

## PRESIDENTIAL ADDRESS

ON

# THE PUBLIC MUSEUM AND EDUCATION

By JOSEPH A. CLUBB, D.Sc.,
*Curator of Museums, Liverpool.*

[Read to the Society, Oct. 12th, 1917.]

As one of the pioneer members of this Society, it has been my privilege to hear a large number of the now lengthy series of Presidential Addresses, and so I have ample evidence of the exceedingly high standard of these discourses. It is, therefore, with the greatest diffidence that I venture to submit to you to-night a few considerations on the Public Museum and Education. To me, personally, it is of course a subject of the greatest possible moment, and I venture to think that there will be no lack of interest in the subject by the members of a Biological Society, seeing how large a percentage of Public Museums are more or less Biological Museums.

The term "Public Museum" is usually applied to Museums supported by public money, to which free access by the public is given. According to the return of a Committee of the British Association in 1887, appointed for the purpose of preparing a Report upon the Provincial Museums of the United Kingdom, there were at that time, in the words of the Report, "about fifty-five museums now the property of Municipal Corporations, and which are nearly all supported by local rates levied under the Public Libraries Act." From a more recent return (1914) this number had then grown to ninety-two. A large proportion

of these museums were originated by local societies, and have been handed over to the municipal authorities for the benefit of the public.

Up to a few years ago, with a few notable exceptions, the collections contained in many of these museums simply presented a heterogeneous collection, with little or no system of arrangement. The adoption of more definite arrangement brought about a stage when the visitor was greeted by row upon row of animals, most literally stuffed, arranged in ranks and accompanied by labels whose principal mission was to convey to the public what to them is a most unimportant matter, the scientific names. But I think it is now generally recognised that the aim of the modern public museum is to illustrate ideas, not merely to display objects, to take the facts or information gathered by long years of patient study, and so present them that they may be understood by everyone. All exhibited specimens should, therefore, have that degree of relation to each other that they may conduce to the same mental impression, if real education is aimed at, and this should be the fundamental principle underlying all modern museum exhibitions.

The educational value of museums is recognised by all universities, inasmuch as every department, where possible, has its museum to enable the student to see the things and realise sensually the qualities described in lessons or lectures—in short, to learn what cannot be learned by words. But the "Teaching Museums" of a university are very different in character from Public Museums. In the first place the *clientèle* is altogether different. The university student comes to his museum primed with the teaching of the classroom, and inspired to acquire knowledge from what may be seen there. There is not the necessity for special preparation to attract the interest, or even to preserve the life-like characters of specimens. So long as a few diagnostic characters are preserved, and may be,

sometimes with difficulty, made out, that is sufficient for a biological specimen in a university Teaching Museum.

But visitors to a Public Museum are as a body totally different. Many go just as they would take a walk, without thought or care as to what they are going to see; others have a vague idea that they will be instructed and civilised, and only a small fraction of the total public go for the definite purpose of acquiring knowledge from the things displayed, or have got ideas about them to be verified, corrected or extended. Hence, the exhibits in a Public Biological Museum must be displayed in a manner to attract the interest of the casual passer-by, and they must be represented in as truly a life-like character as possible. If you cannot interest the visitor you cannot instruct him; if he does not care to know what an animal is or what an object is used for, he will not read the label, be it ever so carefully written. A well-designed, popular Museum should always attract and recreate and excite interest; and the visitor should come and go with the least possible consciousness that he is being educated.

I cannot but briefly touch upon the many methods adopted at the present day by Museum Curators with these aims in view, but I should like to refer in some detail to one of them, and, perhaps the most important, viz., the "Habitat" Groups, and to epitomise the various steps that have led from the dreary exhibits of fifty years ago to the present realistic pictures of animal life that now adorn so many Public Museums. In the old days the principal object in mounting animals, especially mammals, was to preserve them and put them in a condition to be studied and compared one with another. But the science of taxidermy was given a great impetus by this demand for Museum groups. In some ways the task of the taxidermist is more difficult than that of the sculptor who deals only with plastic clay, for the taxidermist has not merely to prepare his model, but, in the case of mammals, to fit over

it a more or less unyielding hide that does not conceal the defects of the model, but has defects of its own to be hidden. Probably no one who has had actual experience in mounting large mammals would question this, though probably few people realise the great progress that has been made in the mounting of animals, particularly large mammals. Not very many years ago animals were most literally stuffed—suspended head downwards and rammed full of straw, often till they could hold no more. These methods were followed by the making of a manikin of tow; next the manikin of wire-netting and papier-mache, and finally the modelling of the animal in clay, giving all detail of muscle contours, etc.—the modelling of this in plaster and the making of a light and durable frame upon which the skin is deftly placed, copying the folds and wrinkles of life.

So far as I can find out, the first to introduce group mounting was an enthusiastic private collector, Mr. E. T. Booth, of Brighton, who devoted a large part of his life to making a collection of British Birds, mounted in various attitudes, with accessories which copied more or less accurately the appearance of the spot where they were taken. As Mr. Booth wrote, "the chief object has been to represent the birds in situations somewhat similar to those in which they were obtained; many of the cases indeed being copied from sketches taken on the actual spots where the birds themselves were shot." These groups were intended to be viewed from the front only, and were arranged in cases of standard size, assembled along the side of a large hall. The collection, which was begun about 1858, was bequeathed to the town of Brighton in 1890, and hence did not appear in a Public Museum until that year. I cannot find out with certainty, but I believe the Liverpool Museum was the first Public Museum, not excepting South Kensington, to exhibit "group" specimens. In the year 1865 a group of the coot was prepared and was exhibited at the

British Association meeting*, held in Birmingham in the same year. This group is still in existence, and, although duplicated by a newer and more up-to-date one, is still on exhibition.

Here, as in so many other directions, although England is the pioneer, she has allowed other countries to outstrip her. In Great Britain we have been content to stop at mammals and birds, and few attempts have been made here to extend "groups" to other animal divisions. It is in America that we find the greatest development of group making. The American has been quick to realise the great educational possibilities of Museum groups in clutching the imagination of the Museum visitor, and no expense has been spared in extending and perfecting their production. After mammals came anything that the American taxidermist or modeller could master—reptiles, amphibians, fishes, insects and other invertebrates, and last of all plants which, when copied by their modern methods, are ever green, and may be made to show their adaptations to environment and inter-relation to varying conditions of soil, climate and surroundings.

Details were given and illustrations shown of a number of the more modern American "Habitat" Groups which may now be seen in the American Museum of Natural History, New York, and other American Museums, where by the aid of enlarged lantern transparencies, painted panoramic backgrounds connected with the foreground, rounded corners and overhead lighting, which permit the last touches in the way of illusion and control of light regardless of the time of day, and produce effects which, to say the least, are extremely striking. The creation of such groups must require a large number of assistants, practically skilled in various directions, in order to carry out the injunctions of the scientists of the staff. Obviously both time and money must be lavishly spent so as to arrive at the state of perfection suggested by these descriptions. Some estimate may be formed, when we consider these

* Report of the British Association, 1865, Miscellaneous communications, p. 92.

facts, of the very high educative value Americans attach to these forms of exhibition.

This section of Museum work was dwelt on in considerable detail, and it was claimed that from the popular standpoint, these " group " exhibits mark a distinct step in Public Museum development, for they serve to emphasize the points of greatest interest to the general public—what the creatures are, where they live and what they do—and they mark a break-away from the old-time collection of natural objects arranged systematically. A limited amount of systematic arrangement may be necessary, for some idea of system is an essential part of scientific education, but the great view of modern science which the general public needs is only in very small part taxonomic.

Another development in educative usefulness of the Public Museum for the general public is in the appointment of Guide Demonstrators, the movement so energetically advocated by Lord Sudeley. It was in April, 1911, that the British Museum organised a system of short lectures and demonstrations, open to the public, and with so much success that the Natural History Museum and the Victoria and Albert Museum followed in the succeeding year with similar arrangements, and there is little doubt but that some of the provincial Museums would have followed suit had it not been for the war. And, without doubt, this is an important step. So many persons have neither the opportunity or the desire to become serious students, but they take an interest in the advancement of Art and Science, and they would like to obtain some knowledge of the world around them and of bygone history. Thus, to this class of the community the Public Museum is increasingly becoming a store-house of information.

The American Museum of Natural History has a Department of Public Education, organised in 1880 for the purpose primarily of familiarizing the teachers of the Public Schools

with the collections on exhibition, by means of lectures illustrated with specimens and lantern slides. From a humble beginning in 1881 the lecture courses rapidly grew in importance, until in 1884 state aid was given to this feature of Museum work, greatly extending its scope and volume.

The authorities of many Museums in this country have realised for some considerable time the great possibilities of a closer co-operation with the schools, and efforts have been made with varying success to bring this about. In Liverpool, since 1884, special circulating Museum cabinets and loan collections have been formed, by means of which Museum specimens have been circulated on loan to any school choosing to make application. In addition, every facility has been given to schools making use of the clause in the Education Code, and bringing classes for instruction in the Museum during school hours. A special lecture room is placed at their disposal to which Museum specimens for purposes of illustration are conveyed, and lantern, operator, and (when required) lantern slides are also provided, and courses of lectures by members of the staff and others have been given in relation to Museum collections and exhibits. In other towns similar arrangements have been in existence. But the education authorities have not responded to any very great extent, and very little systematic use has been made of the facilities available, although every educationist is prepared to admit the educational possibilities of such arrangements. All teachers realise the difficulty of imparting knowledge by mere verbal description—in awakening interest in mere mental pictures, and they know better than anyone else how the tired and anxious face of the child lights up when shown the actual thing—how delighted and anxious it is to see more. The hide-bound syllabus and time-tables of the present system of education may be responsible, but whatever the reason, the fact remains that comparatively little work is being done in this direction in this country. When we enquire what

America is doing, we find a very different state of things. Although probably later in the field, and commencing on very similar lines with the formation of loan collections, the work has now grown to considerable dimensions. From small beginnings this work has progressed until at the present time, in New York and district, nearly four hundred schools, some of which are twenty-five miles from the Museum, are receiving the collections regularly.

The American Museum possesses more than thirty-five thousand lantern slides, of which about twelve thousand are coloured. The field parties which the Museum is sending to remote parts of the earth bring back photographic material, which enables continual additions to be made to this series of slides. The views illustrate plant life, animal life, industries, customs of people and physical geography.

The broad scope of the educational work of the Museum is indicated in the action of the trustees in recently authorizing the equipment of a room especially reserved for the use of the blind. As yet only a small beginning has been made, but specimens of animals and Indian implements have already been set aside and labelled in raised type. The development of this feature of the Museum's activity has been amply provided for by financial bequests. It is safe to say that no visitors to the Museum obtain a greater enjoyment from the collections than do the various groups of blind people, who may often be seen in the exhibition halls.

In an address before the Fourth International Congress of School Hygiene at Buffalo, August, 1913, C. E. A. Winslow, Curator of the Public Health Department of the American Museum, gave an account of the preparations made in the Museum for co-operation in the teaching of school hygiene and sanitation. He claimed the American Museum as the first institution of its kind to grasp the opportunity of attacking the educational problem of public health by the use of Museum

methods. He argued that as man is an animal and public health is one of the most important phases of his natural history, the existence of a Public Health Department in a Natural History Museum was quite logical. Many other interesting details were given of this important work.

These particulars show the vast field of education work covered at the present time by the Department of Education of the American Museum of Natural History, especially in co-operation with public schools. The possible as well as logical points of contact between schools and museums are so numerous as to surprise even those closely in touch with education, and it is claimed by American Museums that there is no sphere of educational work in the public schools of their cities which the Public Museum cannot elaborate or supplement. Vast as this work is, it has grown to its present dimensions in New York in a very few years. It was commenced in a very modest way, and apparently in imitation of similar efforts in Great Britain, by the formation of School Loan Collections. But, whereas in America, and especially in New York, it has grown and extended, the work here has had little or no expansion. They have made progress, whereas we have remained almost stationary. It may be due in some measure to the school system of education in this country, which is being subjected at the present time to so much thought. It is, of course, obvious that any system of education must, as time progresses, require alteration, re-adjustment and amendment to vivify, improve and adapt the system according to altered circumstances, and I am not without hopes that the excellent example of co-operation between Schools and Museums, as seen in New York and other American cities, may have important results in the coming revision of our school education system.

But the Public Museum in this country has got to do its share also, and in accordance with the progressiveness of the times must, while maintaining its stand as an institution of

science, become distinctly identified with public education also. The educative potentialities of Museums must be more fully recognised, especially by their governing bodies. It must be realised that the work of the staff of a Public Museum may rank high in educational importance, and means must be taken to induce and attract intellect and talent for the work. More generous treatment is necessary, especially in the staffing. From returns under this head recently analysed, it is found that the public museums of this country are all lamentably understaffed. For a Public Museum to fulfil its purpose in a conmmunity, authorities will have to realise that sufficient funds must be provided so that the services may be obtained of a qualified scientific head, with a sufficient number of trained assistants, proportionate to the size and importance of the collections and the field (Science, Archæology and Art) covered by them. If this is acted upon as a principle, even the smallest museum with most modest collections could be made of real educational value.

What I should advocate is the formation of a Department of Public Instruction in every Public Museum situated in a large city or centre of population, on similar lines and with similar functions as in the American Museum of Natural History. It should organise and arrange for the distribution of Museum Loan Collections to schools; the arrangements for and delivery of courses of lectures to teachers, pupils and the general public, both inside and outside the Museum, together with the preparation of lantern slides, specimens and other methods of illustration. The entire time and service of this department of the staff should be available to the public at large, and to teachers and classes in particular. In short, its function should be to assimilate the scientific data supplied by the various sections of the museum, and present these facts in such a way that teachers can readily make use of them, and children and the general public easily understand them.

I have dealt exclusively in this address with what may be defined as popular education, but I am the first to recognise that a public museum has a duty to science, and means should be provided whereby the equally important function of scientific research work, looking toward an increase of the sum total of knowledge, can be carried on, and in this way the specialists, attracted by opportunity for scientific work, may also be excellent directors of the educational activities in their own lines, and the numerous specimens required may at the same time serve both scientific and educational ends.

The most discouraging fact concerning our boasted science is that its great teachings, full of meaning for daily life, are so slowly filtering down from the investigators to even many well-educated people, not to mention the great masses with limited or no formal education. We need a rapid expansion of facilities for the promulgation of scientific knowledge among the people. This means a movement along two lines; first, there should be greater attention paid to science teaching in schools and colleges, and second, there is need of a science extension system reaching out to those who have already passed beyond the direct control of regular educational institutions. In both these lines public science museums have an opportunity of playing an important part. They should be valuable supplementary aids to the science studies in educational institutions, and they should be the people's university of science, for the diffusion of scientific knowledge among those not directly reached by teachers.

A public museum with educational aims must be planned to present great principles which make an intellectual appeal; it must teach the application of science to practical life, and it must increase the aesthetic appreciation of nature and nature's processes.

THE

# MARINE BIOLOGICAL STATION AT PORT ERIN

BEING THE

## THIRTY-FIRST ANNUAL REPORT

OF THE

## LIVERPOOL MARINE BIOLOGY COMMITTEE.

By Professor W. A. Herdman, F.R.S.

Once again this Report will deal with little beyond the record of routine work carried out at the Port Erin Biological Station and elsewhere in the L.M.B.C. District.

The "Station Record" and the "Curator's Report" which follow show that during the Easter vacation and the Spring months, when both students and senior workers frequent our marine laboratory more than at any other time of the year, the numbers, though still greatly reduced in comparison with the few years preceding the war, were greater than in 1915. In 1914 we recorded ninety researchers and students occupying work-places in the laboratory; in 1915 we had only fifteen, in 1916 we had twenty-one, and the present report again shows twenty-one. The number of visitors to the Aquarium is larger than it was in 1915, but is far below the numbers usual in previous years.

In regard to the educational work in the laboratories, the usual Easter vacation course in Marine Biology was carried on during April by members of the staff of the Zoology department of the University of Liverpool, and was attended by 12 undergraduates.

Work out at sea was wholly prevented, by Admiralty regulations, but collecting expeditions as usual, along the shore at low tide, were arranged in the Easter vacation. During the remainder of the year the Assistant-Curator made periodic collections from time to time as occasion offered, and plankton

samples were taken across Port Erin Bay with regularity twice in each week, during most weeks in the year. Special series of gatherings were also taken almost daily during April, August and September, as part of the work in connection with the scheme of "Intensive Study of the Plankton" which has now been in progress for over ten years.

It may be useful to students and others proposing to work at Port Erin that the ground plan of the buildings showing the laboratory and other accommodation should be inserted here (see fig. 1, p. 17).

As on previous occasions, the statistics as to the use made of the Laboratories during the year will be given, in the form of a "Curator's Report"; and after that, I have added a short account of the life and work of the recent Oceanographer, Sir John Murray—which seems to follow naturally after the discussion, in last year's Report, of the results of the "Challenger" Expedition. This completes the series of studies of three notable British pioneers in Oceanography, Forbes, Wyville Thomson and Murray, which it is hoped may prove useful for the information of our students and other workers at the laboratory.

## Curator's Report.

Mr. Chadwick reports to me as follows on the various departments of the work:—

### *Station Record.*

"Twenty-one workers—exactly the same number as last year—occupied tables in our laboratories during the past year. Twelve of these were undergraduates of the University of Liverpool, who undertook the fortnight's course of instruction given by Professor Herdman, Mr. R. D. Laurie and Miss R. C. Bamber on the shore, in the field and in the laboratory; the remaining nine were researchers or advanced students.

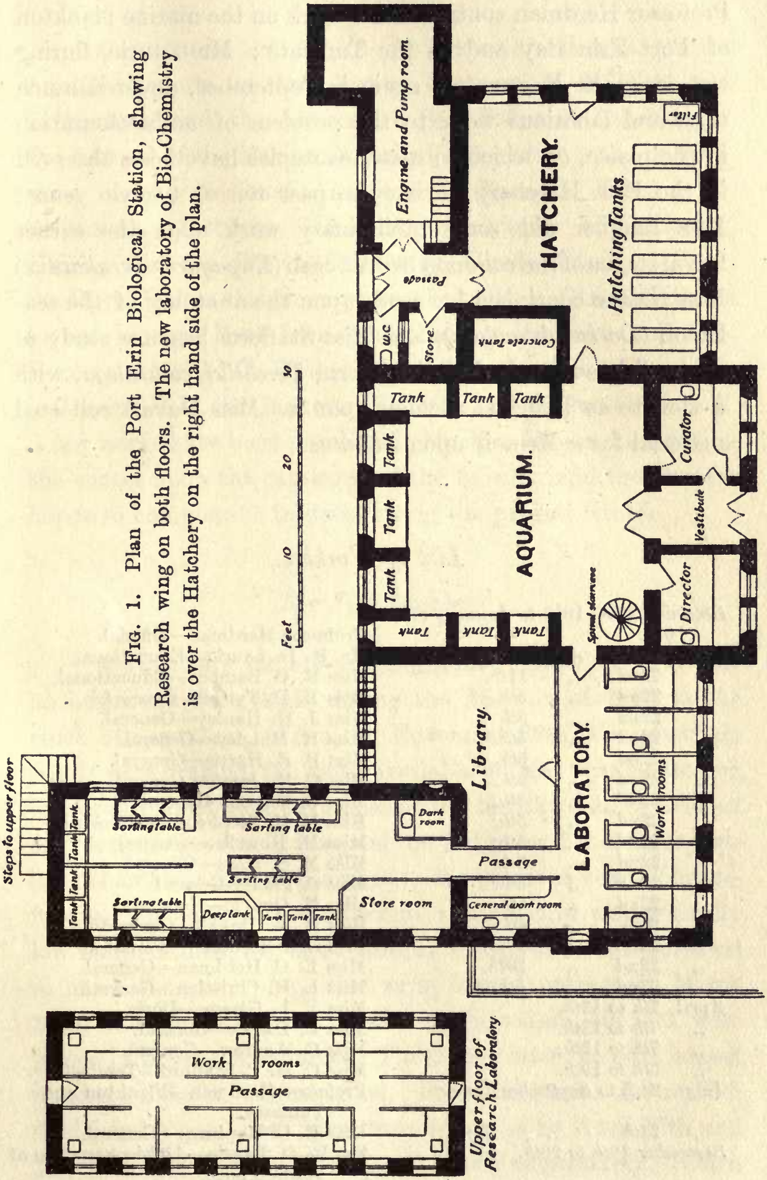



FIG. 1. Plan of the Port Erin Biological Station, showing Research wing on both floors. The new laboratory of Bio-Chemistry is over the Hatchery on the right hand side of the plan.

Professor Herdman continued his work on the marine plankton of Port Erin Bay and on the Tunicata; Mr. Laurie, during two visits, at Easter and again in September, devoted much time and laborious work to the problem of ambicolouration in the plaice, of which so many examples have been observed in the Fish Hatchery during the past ten or twelve years; Miss Bamber did some preliminary work upon the earlier larval stages of the common hermit crab (*Eupagurus bernhardus*) Miss Gleave continued her work upon the anatomy of the sea-lemon (*Doris tuberculata*), and Miss Stafford began a study of the well-known tube-building worm *Terebella conchilega*, with a view to an L.M.B.C. Memoir upon it. Miss Duvall collected material for a Memoir upon *Balanus*.

*List of Workers.*

| | |
|---|---|
| *December* 26*th*, 1916 *to January* 8*th*, 1917. | Professor Herdman—Official. |
| *March* 22nd *to April* 11*th*. | Mr. R. D. Laurie—Educational. |
| ,, 22*nd* ,, 11*th*. | Miss R. C. Bamber—Educational. |
| ,, 22*nd* ,, 5*th*. | Miss B. D. Tyrrell—General. |
| ,, 22*nd* ,, 5*th* | Miss J. H. Hanley—General. |
| ,, 22*nd* ,, 5*th*. | Miss H. Midgley—General. |
| ,, 22*nd* ,, 5*th*. | Miss P. E. Harris—General. |
| ,, 22*nd* ,, 5*th*. | Miss C. M. Jarvis—General. |
| ,, 22*nd* ,, 5*th*. | Miss C. Mayne—General. |
| ,, 22*nd* ,, 5*th*. | Miss E. M. Stephenson—General. |
| ,, 22*nd* ,, 5*th*. | Miss M. Howells.—General |
| ,, 22*nd* ,, 5*th*. | Miss M. S. Moss—General. |
| ,, 22*nd* ,, 5*th*. | Miss S. Firth—General. |
| ,, 22*nd* ,, 5*th*. | Miss M. Quayle—General |
| ,, 28*th* ,, 4*th*. | Miss H. M. Duvall—Cirripedia. |
| ,, 22nd ,, 20*th*. | Professor Herdman—Plankton. |
| ,, 22*nd* ,, 20*th*. | Miss E. C. Herdman—General. |
| ,, 22*nd* ,, 5*th*. | Miss L. M. Christian—General. |
| *April* 7*th to* 13*th*. | Miss E. L. Gleave—Doris. |
| ,, 7*th to* 13*th*. | Miss L. Davies—General. |
| ,, 7*th to* 13*th*. | Miss G. Andrew—General. |
| ,, 5*th to* 19*th*. | Miss C. M. P. Stafford—Terebella. |
| *July* 24*th to September* 22*nd*. | Professor Herdman—Plankton and Tunicata. |
| ,, 24*th* ,, 22*nd*. | Miss E. C. Herdman—General. |
| *September* 19*th to* 26*th*. | Mr. R. D. Laurie—Ambicolouration of young Plaice. |

*The Library.*

"Our thanks are due to the respective donors for the Annual Reports of the Marine Stations of Millport and Cullercoats, and the Lancashire Sea Fisheries Laboratory; the Journal of the Marine Biological Association; the publications of the National Academy of Sciences, U.S.A., the Smithsonian Institute, U.S.A., the University of California, U.S.A., and the Brown University, Rhode Island, U.S.A.; the Royal Italian Oceanographical Committee. Other additions to the Library have been presented by Professor and Mrs. Herdman, Mr. A. O. Walker, the Secretary of State for India in Council, H.H. the Gaekwar of Baroda and Mr. James Hornell. A few works have been purchased. Much work was done during the winter upon the catalogue of the Library, and the Curator hopes to complete it to date during the present winter.

*The Fish Hatchery.*

"Owing very largely to conditions imposed by the war, no additions were made during the Autumn of 1916 to the stock of spawners. When, on November 28th, the spawning ponds were drained, the stock available for this year's hatching operations was found to consist of 102 healthy fish. Fertilised eggs were first seen in the pond on February 22nd, three days later than their first appearance in the previous year. Thenceforward, in spite of much severe weather and exceptionally low temperatures, the daily number of eggs collected increased in much the same proportion as in former years until March 24th, when the maximum number of the season, 504,000, were placed in the hatching boxes. Three days later the next largest number, 493,500, was recorded. From that time the number fluctuated a good deal from day to day, as on April 11th and 12th, when there were 283,500 and 63,000 respectively. When

the season was somewhat advanced it was found that 19 fish which were hatched and reared during the season of 1914, and had attained an average length of 10½ inches, were spawning. The eggs produced by these fish were smaller than the average size of the egg of the plaice, the proportions being as 5 to 6·5, but they were otherwise normal.

"The Hatchery Record, giving the number of eggs collected and of larval fish set free on the various days, is as follows:—

| Eggs collected. | Date. | | Larvae set free. | Date. | |
|---|---|---|---|---|---|
| 75,600 | ... Feb. | 22 to 27 | 64,050 | ... March | 23 |
| 163,800 | ... ,, | 28 and March 2 | 151,200 | ... ,, | 27 |
| 430,000 | ... March | 3 and 8 | 409,500 | ... April | 3 |
| 455,700 | ... ,, | 10 and 12 | 418,950 | ... ,, | 6 |
| 628,950 | ... ,, | 13 to 20 | 549,150 | ... ,, | 11 |
| 420,000 | ... ,, | 21 and 22 | 386,400 | ... ,, | 14 |
| 504,000 | ... ,, | 24 | 454,650 | ... ,, | 17 |
| 844,200 | ... ,, | 27 to 30 | 764,450 | ... ,, | 19 |
| 537,600 | ... ,, | 31 to April 4 | 443,100 | ... ,, | 24 |
| 390,600 | ... April | 5 and 7 | 326,550 | ... ,, | 28 |
| 346,500 | ... ,, | 11 and 12 | 301,350 | ... ,, | 30 |
| 189,000 | ... ,, | 16 | 163,800 | ... May | 2 |
| 504,000 | ... ,, | 17 to 20 | 409,500 | ... ,, | 4 |
| 147,000 | ... ,, | 21 | 126,000 | ... ,, | 7 |
| 310,800 | ... ,, | 24 and 26 | 268,500 | ... ,, | 9 |
| 88,200 | ... ,, | 28 | 79,800 | ... ,, | 10 |
| 42,000 | ... May | 1 | 31,500 | ... ,, | 12 |
| 6,077,950 | Total eggs. | | 5,348,450 | Total larvae. | |

"The plaice hatching operations were conducted solely by the Assistant Curator, Mr. T. N. Cregeen.

*Lobster Culture.*

"Though the number of larvae set free during the lobster hatching season was not large, the percentage reared to the lobsterling stage was considerably larger than that of any

previous season; and the general result reflects credit upon the Assistant Curator, who, again, had entire charge of the work and whose efforts were untiring. Eleven female lobsters were purchased from local fishermen, and the eggs of these yielded 4,142 larvae. Two thousand eight hundred larvae were set free in the first stage; the remaining 1,342 were transferred from the spawning pond to a number of half-gallon glass jars, placed in convenient rows in the Hatchery. At the beginning of the season 12 larvae were put into each jar, but though the water was changed frequently, experience showed that a smaller number gave better results, and later on the number was reduced to 6. The larvae were fed exclusively upon plankton, which the experience of the past two or three seasons has shown to be the best food. The total number of lobsterlings thus reared was 300. Two hundred and eighty-five were set free in chosen spots where they would find shelter, and 15 have been retained for further experiments in rearing.

### *The Aquarium.*

"Three thousand two hundred and nineteen visitors paid for admission to the Aquarium during the year. The small increase in numbers as compared with the previous year—169—is somewhat disappointing, considering that it was proportionately much larger from Easter until the early part of August, when persistent unseasonable weather checked the inflow of visitors. The specimens exhibited in the tanks were much the same as those of previous years, with the notable exception of the octopus of the Irish Sea, *Eledone cirrosa*. For the first year in the history of the Institution, not a single specimen of this exceptionally interesting animal was obtainable, much to the disappointment of many visitors. Plaice hatched and reared in the Hatchery in 1914, 1915 and 1916 were exhibited

in several tanks and fully maintained the interest shown by the visitors of previous years in our economic work. The lobster larvae also excited much interest. The display of sea-anemones in the table tanks never fails to attract attention; and to these Miss E. C. Herdman, at the latter end of the season, added a number of interesting species—*Ciona intestinalis*, *Sabella pavonia*, *Eolis rufibranchialis*, *Doto fragilis*, *Idotea marina* (both sexes and young), *Antedon bifida* and others. A group of specimens of the sand anemone, *Halcampa crysanthellum*, inhabit a small glass dish filled with sand, and afford a remarkable example of the very close resemblance, in colour and markings, of many marine animals to their surroundings. The disk and tentacles of *Halcampa* present the same speckled appearance as the sand on which the latter are allowed to rest when the animal is fully expanded, and are not easy to detect, even to the practised eye. A large specimen of the Mollusc *Pleurobranchus membranaceus* was one day seen to swim voluntarily round and round the table tank in which it lived for some time during the summer. Swimming was effected by the lateral margins of the foot, which, with graceful curvature, were flapped dorsally and ventrally in much the same way as a skate or ray uses its lateral 'wings.' The animal was under observation for about twenty minutes, during which time it swam actively, with only two or three brief intervals of rest. Less than an hour before this it deposited a large coil of spawn on the gravel at the bottom of the tank.

## *General.*

"The occurrence of various Invertebrates, especially medusæ, in our spawning ponds has been recorded from time to time in our Annual Reports. This year a species of *Sarsia* appeared in large numbers during the plaice hatching season. Mr. E. T. Browne, to whom specimens were submitted for

identification, writes that they were in too early a stage to enable him to recognise the species. It is curious that in spite of careful search the hydroid stocks from which this and other previously recorded medusæ have arisen have not been found in the pond. When the ponds were drained for their annual cleaning in September, various other Invertebrates were found. On the vertical wall at one end of the lobster pond a colony of the barnacle *Balanus balanoides* had established themselves and attained a considerable size, and a well-grown

FIG. 2. Colony of *Tubularia larynx* in aquarium jar. Two-thirds nat. size.

specimen of the Polynoid worm *Lepidonotus squamatus* was found in the larger plaice pond. Great swarms of the Copepod *Acartia clausi* were seen in the smaller plaice pond as the water was drained from it.

The common limpet, *Patella vulgata,* and the periwinkle, *Littorina rudis,* are now well-established inhabitants of the

storage tanks, but do not appear in the spawning ponds. This is probably accounted for by the daily varying level of the water in the former, which to some extent resembles the ebb and flow of the tide on the beach. Early in August the growth of a colony of the beautiful Hydroid *Tubularia larynx* was noticed in one of the half-gallon glass jars used for rearing lobster larvae in the Hatchery. The first polyp of the colony had established itself at the bottom and close to the side of the jar, and from it the creeping stolons subsequently grew to left and right along the junction of the side with the bottom of the jar, and to a small extent over the latter. Polyps arose at frequent intervals from the stolons, and were frequently seen to catch with their tentacles and feed upon the Copepods which were put into the jar as food for the lobster larvae. The colony attained a length of 3½ inches (see fig. 2).

(Signed) H. C. CHADWICK."

## REPORT OF THE EDWARD FORBES EXHIBITIONER.

An "Edward Forbes Exhibition" was founded* in 1915, at the University of Liverpool, in commemoration of the pioneer marine biological work done in this district by the celebrated Manx Naturalist, who was born about a hundred years ago. The object of the Exhibition is to enable some post-graduate student of the University to proceed to the Port Erin Biological Station for the purpose of carrying on some piece of biological research, more or less in continuation of some line of work opened up by Forbes, or an investigation which has grown out of such work.

The Edward Forbes Exhibitioner for the year 1917 is CHARLOTTE M. P. STAFFORD, B.Sc., who spent a couple of weeks at Port Erin in the Spring, working at some points in

* The Regulations in regard to the Exhibition will be found at p. 67.

the structure of the Tubicolous Annelid, *Terebella conchilega*, with a view of preparing an L.M.B.C. Memoir on the subject. Miss Stafford reports as follows on her work at Port Erin :—

" During my fortnight's stay at Port Erin, from 5th April to 20th April, the aim of my work was twofold :—

1. To examine, in their natural habitat and in tanks at the Biological Station, living specimens of *Terebella conchilega.*
2. To preserve material of this species for further examination at Liverpool.

" For collecting purposes the tides were very suitable. The small sandy tubes, often with fringed ends and standing up, or bending over, about 1 inch above the surface of the sand, indicated where *Terebella* could be found. It occurs between low and high water marks of ordinary tides, the zone just above low water mark being very densely crowded, although they are not nearly so thick just above low water mark of a spring-tide. Considerable care is necessary, while digging for *Terebella,* in order to remove the tube from the sand without damaging the worm and before it has time to withdraw to any great depth.

" The tube-building habits of this worm have been worked out in great detail and described by Mr. A. T. Watson (*Journ. R. Micro. Soc.*, 1916, pp. 253-256) ; but, from the point of view of general interest, I kept several worms, which I had removed from their tubes to shallow glass tanks, and made observations on their building habits on lines kindly suggested by Mr. Watson. I was fortunate enough to be able to see many of the wonderful actions, which he has described, and was struck with the remarkable activity exhibited.

" With regard to preparations for preserving material, it was first necessary to remove the worms from their tubes and keep them for two or three days before fixing them in order to make certain that all sand had been voided from the

intestine. This is of the utmost importance in the case of specimens intended for microtome sectionising.

"Killing and fixing methods were at first wholly experimental, and later I fixed the bulk of my material according to the best results obtained. Worms killed by chloroform, or by chloroform vapour, appeared to show signs of maceration after a few hours. Those killed in formol gave better promise of suitable material for dissection purposes. For sectionising purposes, the apparently most successful results were obtained with acid corrosive sublimate and Bouin's Fluid. Still others I gradually narcotised with alcohol and then extended them completely before fixing with absolute. The value of these methods will be ultimately decided by the results they yield on further investigation, but undoubtedly each will have its worth in some one particular direction.

"I obtained and fixed sufficient material for a considerable amount of work at Liverpool, where I shall continue the investigation.

"I acknowledge and appreciate the help given me in connection with this work, both at Liverpool and Port Erin, where the Curator and Assistant Curator made valuable suggestions, and helped in carrying them out.

(Signed) Charlotte M. P. Stafford."

## L.M.B.C. Memoirs.

Since our last report was published, no further Memoirs have been issued to the public. Himanthalia, by Miss L. G. Nash, M.Sc., is ready to print; Miss E. L. Gleave, M.Sc., has nearly completed her Memoir on Doris, the Sea-lemon; Mr. Burfield, who was writing the Memoir on Sagitta, has joined the Army; Miss Bamber has made further progress with Tubularia, and still other Memoirs are in preparation.

The following shows a list of the Memoirs already published or arranged for :

I. Ascidia, W. A. Herdman, 60 pp., 5 Pls.
II. Cardium, J. Johnstone, 92 pp., 7 Pls.
III. Echinus, H. C. Chadwick, 36 pp., 5 Pls.
IV. Codium, R. J. H. Gibson and H. Auld, 3 Pls.
V. Alcyonium, S. J. Hickson, 30 pp., 3 Pls.
VI. Lepeophtheirus and Lernæa, A. Scott, 5 Pls.
VII. Lineus, R. C. Punnett, 40 pp., 4 Pls.
VIII. Plaice, F. J. Cole and J. Johnstone, 11 Pls.
IX. Chondrus, O. V. Darbishire, 50 pp., 7 Pls.
X. Patella, J. R. A. Davis and H. J. Fleure, 4 Pls.
XI. Arenicola, J. H. Ashworth, 126 pp., 8 Pls.
XII. Gammarus, M. Cussans, 55 pp., 4 Pls.
XIII. Anurida, A. D. Imms, 107 pp., 8 Pls.
XIV. Ligia, C. G. Hewitt, 45 pp., 4 Pls.
XV. Antedon, H. C. Chadwick, 55 pp., 7 Pls.
XVI. Cancer, J. Pearson, 217 pp., 13 Pls.
XVII. Pecten, W. J. Dakin, 144 pp., 9 Pls.
XVIII. Eledone, A. Isgrove, 113 pp., 10 Pls.
XIX. Polychaet Larvæ, F. H. Gravely, 87 pp., 4 Pls.
XX. Buccinum, W. J. Dakin, 123 pp., 8 Pls.
XXI. Eupagurus, H. G. Jackson, 88 pp., 6 Pls.
XXII. Echinoderm Larvæ, H. C. Chadwick, 40 pp., 9 Pls.
XXIII. Tubifex, G. C. Dixon, 100 pp., 7 Pls.
Himanthalia, L. G. Nash.
Doris, E. L. Gleave.
Tubularia, R. C. Bamber.
Aplysia, N. B. Eales.
Terebella, C. P. M. Stafford.
Balanus, H. M. Duvall.
Sagitta, S. T. Burfield.
Actinia, J. A. Clubb.
Zostera, R. Robbins.

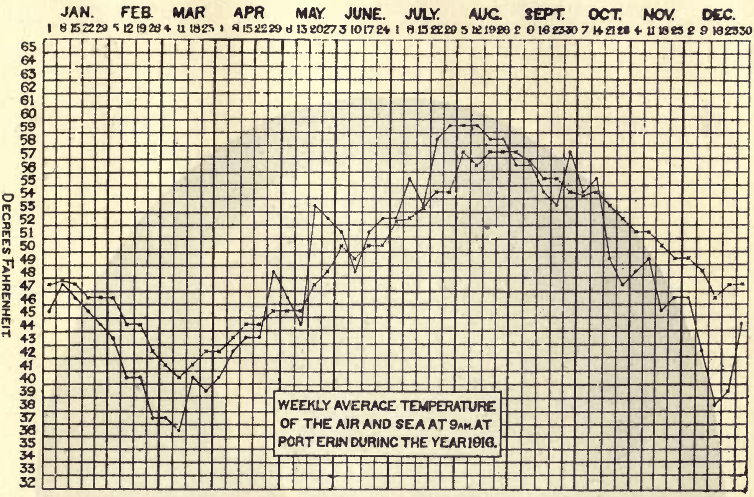
HALICHONDRIA AND SYCON, A. Dendy.
OYSTER, W. A. Herdman and J. T. Jenkins.
SABELLARIA, A. T. Watson.
OSTRACOD (CYTHERE), A. Scott.
ASTERIAS, H. C. Chadwick.
PYCNOGONUM, J. E. Hamilton.
BOTRYLLOIDES, W. A. Herdman.

In addition to these, it is hoped that other Memoirs will be arranged for, on suitable types, such as *Pontobdella*, a Cestode and a Nematode.

As the result of a slight fire in the Zoology Department of the University, a portion of the stock of L.M.B.C. Memoirs has been partially destroyed. There are a certain number of damaged copies of some of the Memoirs which are stained or singed externally, but are still quite usable, and are suitable for laboratory work. The Committee has decided to offer these at prices ranging according to the condition from one-half to one-fourth of the published prices, as follows:—Memoir I., Ascidia, 6d. to 9d.; VI., Lepeophtheirus and Lernæa, 6d. to 1s.; VII., Lineus, 6d. to 1s.; XIII., Anurida, 1s. to 2s.; XIV., Ligia, 6d. to 1s.; XV., Antedon, 6d. to 1s. 3d.

Orders for these damaged copies should be sent to Professor Herdman, the University, Liverpool. New copies of any of the Memoirs should be ordered from Williams & Norgate.

The diagram of sea and air temperatures for 1917, compiled by Mr. Chadwick from his daily records, is not yet completed; but that for the preceding year, 1916, is inserted here as usual.

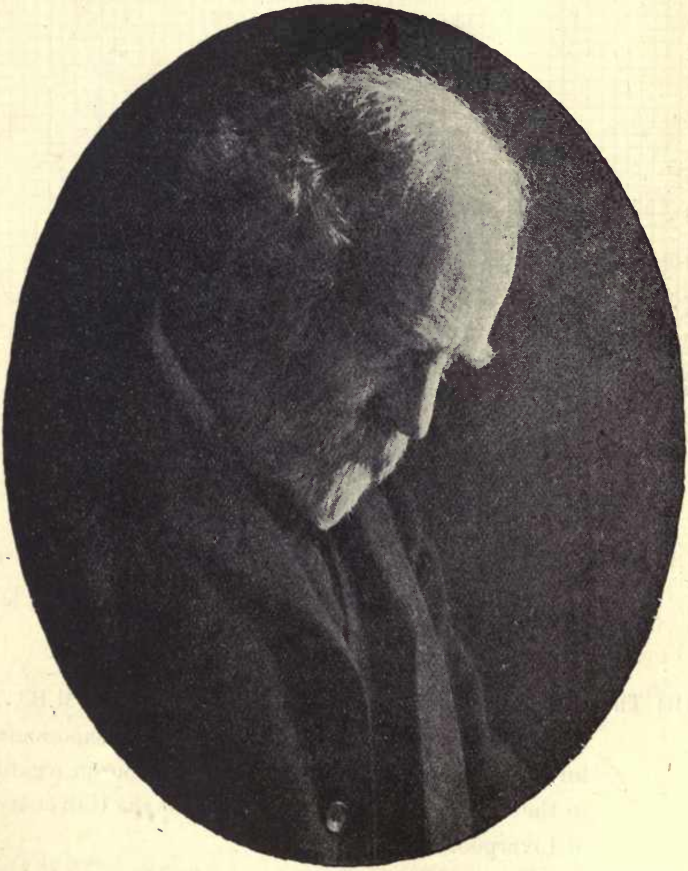



Appended to this Report are :—

(A) An Address on " Sir John Murray, the Pioneer of Modern Oceanography," delivered to the Biological Society, by Professor Herdman, on November 9th, 1917 ;

(B) The usual Statement as to the constitution of the L.M.B.C., and the Laboratory Regulations—with Memoranda for the use of students, and the Regulations in regard to the " Edward Forbes Exhibition " at the University of Liverpool ;

(C) The Hon. Treasurer's Report, List of Subscribers, and Balance Sheet for the year.



SIR JOHN MURRAY.

From a photograph taken about 1911.

## APPENDIX A.

AN ADDRESS UPON

# SIR JOHN MURRAY, K.C.B., F.R.S., THE PIONEER OF MODERN OCEANOGRAPHY.

GIVEN BEFORE THE LIVERPOOL BIOLOGICAL SOCIETY

By W. A. HERDMAN.

I desire to lay before you on the present occasion the third and last of this short series of studies of those notable pioneers in British Marine Biology leading on to Oceanography, Professor Edward Forbes, Sir Wyville Thomson and Sir John Murray. During these last three years of war our usual biological work at sea has been impossible, and it seemed fitting that the opportunity should be taken to lay before our students some record of those who had established a Science of the Sea in our country. In 1915 our thoughts were naturally turned to Edward Forbes by the centenary of his birth, which was celebrated that year. The following year (1916) it seemed natural to talk of Wyville Thomson, who extended to the depths of the great oceans those methods of exploration which Forbes had started on the coasts of Europe. Finally, in 1917, we realise that Murray continued and completed the work of Thomson, in addition to undertaking other more recent investigations. While Sir Wyville Thomson's name will always be remembered as the leader of the "Challenger" Expedition, Sir John Murray will be known in the history of Science as the Naturalist who brought to a successful issue the investigation of the enormous collections and the publication of the scientific results of that memorable voyage: these two Scots share the honour of having guided the destinies of what is still the greatest oceanographic exploration of all times.

John Murray, although a typical Scot in all his ways, was born in Canada—at Coburg, Ontario, on March 3rd, 1841. But he was of Scottish descent, and returned in early life to maternal relatives in Scotland to complete his education. The lives of our three pioneers just occupied a century (1815 to 1914), and to some extent overlapped. Forbes was only fifteen years senior to Wyville Thomson, and Thomson eleven years senior to Murray. While John Murray was still a school-boy in Upper Canada, Forbes was running his brief meteoric career as Professor in Edinburgh, and Wyville Thomson was a young lecturer on the Natural Sciences in Ireland. Curiously enough all three went through unusually extended courses as students of Medicine and Science at the University of Edinburgh, and not one of them took a degree. Forbes was a genius who neglected his work and frankly "funked" his examinations when the time came. In Thomson's case ill-health, fortunately for Science, stopped his proposed career in Medicine; while Murray despised examinations and degrees and probably never proposed to take them. He studied a subject because he wanted to know it, and in that spirit he ranged widely over the Faculties of his University. When I was a student and young graduate I used to hear him denounce in vigorous language all examinations and other formal tests of knowledge, and yet, late in life there was probably no man of his time who had so many honorary degrees and titles conferred upon him by the Universities and learned Academies of Europe and America.

After returning to Scotland as a boy in the teens, he lived for some time with a grandfather at Bridge of Allan, and attended the High School at Stirling. During this time he seems to have been most interested in the physical sciences, and especially electricity. He established some electrical apparatus at his home, and in an address to his old school, in 1899, he gives an amusing account of some of the results of his experiments with a large induction coil, such as the

following:—"On another occasion, several companions arrived from Stirling to see my experiments; they had with them five dogs, one of them being 'Mysie,' a large dog belonging to Sir John Hay, and I had a large Newfoundland called 'Max.' We resolved to give the dogs a shock. They were duly arranged in the room, and the circuit was completed by bringing the noses of the two largest dogs together. Pandemonium was the result. Each dog believed he had been bitten by the other. They fought, chairs and tables were over-turned, and much of the apparatus broken. In the future, I was requested to turn my attention to the observational sciences of botany, zoology, and geology."

He then spent some years, in the 'sixties, at the University of Edinburgh where he was known as a "chronic" student, working at the subjects in which he was interested without following any definite course. Amongst the Professors under whom he studied at that time, and who became his close friends in later life, were P. G. Tait in Physics, Crum Brown in Chemistry, Turner in Anatomy, and Archibald Geikie in Geology. A decade or so later, after the return of the "Challenger" Expedition, he became once more a student at the University of Edinburgh, and that was when I had the good fortune first to meet him.

In 1868 he visited Spitzbergen and Jan Mayen and other parts of the Arctic regions on board a Peterhead whaler, on which, on the strength of having once been a medical student, he was shipped as surgeon. This voyage of seven months probably did much to confirm that interest in the phenomena and problems of the Ocean which had been first aroused on his passage home from Canada, ten years before. This interest was doubtless further stimulated during the immediately following years by the epoch-making results of the pioneer deep-sea expeditions in the "Lightning" and "Porcupine," which explored, under the direction of Wyville Thomson,

Carpenter and Gwyn Jeffreys, the Atlantic coasts of Europe. And then, fortunately, in 1870, Wyville Thomson was appointed Professor at Edinburgh, which now became the centre of the negotiations and arrangements with the Admiralty and the Royal Society that led eventually, in 1872, to the equipment and despatch of our great British Deep-Sea Exploring Expedition.

It was only an odd chance that led to Murray's connection with the "Challenger." The scientific staff had already been definitely appointed when, at the last moment, one of the Assistant Naturalists dropped out, and mainly on the strong recommendation of Professor Tait, in whose laboratory Murray was at the time working, Sir Wyville Thomson offered him the vacant post—surely one of the best examples in the history of Science of the right man being chosen to fill a post.

In addition to taking his part in the general work of the Expedition, Murray devoted special attention to three subjects of primary importance in the science of the sea, viz., the plankton or floating life of the oceans, the deposits forming on the sea bottoms, and the origin and mode of formation of coral reefs and islands. It was characteristic of his broad and synthetic outlook on nature that, in place of working at the speciography and anatomy of some group of organisms, however novel, interesting, and attractive to the naturalist the deep-sea organisms might seem to be, he took up wide-reaching general problems with economic and geological as well as biological applications. Amongst the preliminary reports sent home during the course of the expedition, and published in the Proceedings of the Royal Society (Vol. XXIV., No. 170, p. 471), we find those by John Murray, written from Valparaiso, 9th December, 1875, dealing with (1) Oceanic Deposits, (2) Surface Organisms and their relation to Oceanic Deposits, and (3) Vertebrata (mainly Fishes) which, though superseded by the later work of himself and others, are still of

great historic interest. In that preliminary account of the Oceanic Deposits we find Murray's first classification into (1) Shore deposits, (2) Globigerina ooze, (3) Radiolarian ooze, (4) Diatomaceous ooze, and (5) Red and Grey Clays, which has been adopted with little or no change in all succeeding works; and, in his report on the surface organisms, we find the first figures of the living *Hastigerina*, *Pyrocystis* and the remarkable deep-water Radiolaria known as "Challengeridæ."

Each of the three main lines of investigation—deposits, plankton and coral reefs—which Murray undertook on board the "Challenger" has been most fruitful of results both in his own hands and those of others. His plankton work has led on to those modern planktonic researches which are closely bound up with the scientific investigation of our sea-fisheries. His observations on coral reefs, in conjunction with the "Challenger" results as to depths of the ocean and the presence of submarine volcanic elevations, resulted in his new and most original theory as to the formation of "Atolls," which removed certain difficulties that had long been felt by zoologists and geologists alike to stand in the way of the universal acceptance of Darwin's well-known theory of coral reefs and islands.

His work on the deposits accumulating on the floor of the ocean resulted, after years of study in the laboratory as well as in the field, in collaboration with the Abbé Renard of the Brussels Museum, afterwards Professor at Ghent, in the production of the monumental "Deep-Sea Deposits" volume, one of the "Challenger" Reports, which first revealed to the scientific world the detailed nature and distribution of the varied submarine deposits of the globe and their relation to the rocks forming the crust of the earth.

These studies led, moreover, to one of the romances of Science which deeply influenced Murray's future life and work. In accumulating material from all parts of the world and all deep-sea exploring expeditions for comparison with

the "Challenger" series, some ten years later, Murray found that a sample of rock from Christmas Island in the Indian Ocean, which had been sent to him by Commander (now Admiral) Aldrich of H.M.S. "Egeria," was composed of a valuable phosphatic deposit.

Murray's interest in this rock was at first solely in relation to the "Challenger" deposits and its possible bearing on his coral reef theory; but he soon realised its economic as well as scientific interest, and was convinced that the Island would be of value to the nation. After overcoming many difficulties he induced the British Government to annex this lonely, uninhabited volcanic island, and to give a concession to work the deposits to a company which he formed. He sent out scientific investigators to study and report on the products of the island, and the results have been highly successful on both the scientific and the commercial sides. Sir John Murray visited Christmas Island himself on several occasions, he had roads cleared, a railway constructed, waterworks established, piers built and the necessary buildings erected. In fact, the lonely island was colonised by about 1,500 inhabitants, and flourishing plantations of various kinds were established in addition to the working of the phosphatic deposits. Murray was able to show that some years ago the British Treasury had already received in royalties and taxes from the island considerably more than the total cost of the "Challenger" Expedition.

This is one of these cases where a purely scientific investigation has led directly to great wealth—wealth, it may be added, which in this case has been used to a great extent for the advancement of Science.

In the case of Sir John Murray, as in that of my address on Sir Wyville Thomson last year, I am writing of a man who made a strong personal impression as one of my teachers in Science at Edinburgh forty years ago. It is not from one's

formal instructors alone that one learns. Murray was never on the teaching staff of the University; but a few of us (generally Sir David Bruce, now of the War Office, Professor Noel-Paton, now of Glasgow, and myself), who were then, in the late 'seventies, young students of Science, and were privileged to have the run of the "Challenger" Office, learned more of practical Natural History from John Murray than we did from many University lectures.

This was in the few years following on the return of the "Challenger" Expedition in 1876, and the vast collections of all kinds brought back from all the seas and remote islands were being classified and sorted out into groups for further examination in a house near the University, known as the "Challenger Office." Murray, as First Assistant on the Staff, had charge of the office and the collections, and welcomed a few eager young workers who were willing to devote free afternoons to helping in the multifarious work always in progress.

There we first made acquaintance with the celebrated new deep-sea "oozes," learnt to distinguish them under the microscope and how to demonstrate the silicious Radiolaria hidden in the calcareous Globigerina ooze; and there we first saw such wonders of the deep as *Holopus* and *Cephalodiscus* and the extraordinary new abyssal Holothurians, afterwards known as Elasipoda. These—now the common-places of marine biology—were then revelations, and those of us who witnessed the discoveries in-the-making will always associate them with "Challenger Murray" as the arch-magician of the laboratory—a sort of modern scientific astrologer, bringing mysterious unknown things out of store-bottles, and then showing us how to demonstrate their true nature. I am afraid that we who are trying to inspire students with the sacred fire at the present day have no such wonders to show as those first-fruits in the early days of deep-sea research. Then between

times, while waiting for a reaction, or after work, Murray would tell us stories of the great expedition—how the first living *Globigerina* (*Hastigerina murrayi*) seen in all its glory of vesicular protoplasm expanded far beyond its tiny shell was picked up in a teaspoon from a small boat during a dead calm in mid-ocean; and how the naval officers wrote their names with their fingers in letters of fire on the phosphorescing giant *Pyrosoma* (over 4 feet long) as it lay on the deck at night; how they "iced" their champagne in the tropics by plunging the bottles into the trawlful of ooze just brought up from the abyss, and still retaining its abyssal low temperature; and, finally, he would sing us a most amusing song—we never knew whether he had invented it or not—about a Chinaman eating a little white dog.

A few years later, after Sir Wyville Thomson's death in 1882, Murray had supreme control of both the collections and the editing of the Reports; and of the "Office," by that time moved to more commodious quarters at 32, Queen Street, which was the scene of his labours for many years, and where I for a time held the post of "Assistant-Naturalist," and saw Murray practically every day.

When I first knew John Murray, although he was an older man, we were really in one respect fellow-students, as we attended together Professor Archibald Geikie's course on Geology. One very pleasant and not the least instructive part of the course at that time was the series of geological walks personally conducted by the professor, not merely Saturday walks in the neighbourhood of Edinburgh, but also longer expeditions of a week or ten days at the end of the session, to localities of special geological interest further afield, such as the Highlands or the Island of Arran. I well remember one such long excursion to the Grampian and the Cairngorm Mountains and Speyside, when we had, as somewhat senior members of the party—in addition to Professor Geikie—

Dr. Benjamin Peach and Dr. John Horne of the Geological Survey, Dr. Aitken of the University Chemical Department, Joseph Thomson the African explorer, and John Murray of the "Challenger." The rest of us were ordinary students of Science, and you can realise how we enjoyed and profited by the conversation of these senior men, how we dogged their steps and hung upon their every word. All who ever met John Murray will readily understand that in the frequent discussions that took place between these geologists and chemists, he always took a leading and forcible part—he was nothing if not original in his views and vigorous in his language.

Murray's first paper on his theory of Coral Reefs was read before the Royal Society of Edinburgh on 5th April, 1880, and was published in the *Proceedings*, Vol. X, p. 505. I well remember the occasion, and also the rehearsal which took place some days before in Sir Wyville Thomson's house of Bonsyde, when Murray read his MS. to a small but highly critical audience, consisting of Sir Wyville Thomson, Sir William Turner and myself. For months before I had daily seen Murray preparing the paper in a large room at the "Challenger Office," sitting at his notes in the centre of a multitude of charts showing all the reefs and coral islands of tropical seas—some of the charts spread out on tables, others carpeting the floor or stacked in piles and rolls—while he measured and drew sections of the contours so as to see which reefs supported his views and which presented difficulties. His coral reef theory was a direct outcome of his "Challenger" work. The soundings had revealed the presence of volcanic elevations, and the distribution of the calcareous deposits showed how these might contribute to build up suitable platforms as the foundation of reefs which might grow to the surface independent of all sunken lands, such as Darwin's theory had required. It may be said that Murray demolished the supposed need of vast oceanic subsidence, which had been

felt to be a difficulty by many geologists, and showed that all types of coral reef could be accounted for without subsidence, and even in some cases along with elevation of land.

Some of Murray's friends were disappointed that his theory did not receive more serious and more immediate attention, and the then Duke of Argyll wrote a couple of articles with somewhat sensational titles—"A Great Lesson," in the *Nineteenth Century* for September, 1887, and "A Conspiracy of Silence," in *Nature* for November 17th, 1887—which gave rise to answers from some of the leading men of Science of the day, Huxley, Bonney and Judd. Murray went on his way undisturbed, collecting further evidence and publishing at intervals further papers dealing with one or another part of the large subject—such as his paper on the structure and origin of Coral Reefs in the *Proceedings* of the Royal Institution for 1888, his account of the Balfour Shoal in the Coral Sea (1897), a submarine elevation being built up by calcareous deposits, his "Distribution of Pelagic Foraminifera at the surface and on the floor of the Ocean" (1897), and a series of reports upon bottom deposits from the "Blake" (1885) and many other expeditions.

Later on (1896-98) Murray took a lively interest in the investigation, by a Committee of the British Association and the Royal Society, of a selected typical case, the atoll of Funafuti, one of the Ellice Group, in the South Pacific. A first expedition was sent out from this country under Professor Sollas, and then two others from Australia, under Professor Edgeworth David of Sydney, and borings were eventually obtained reaching an extreme depth of over 1,100 feet. The core was brought home and subjected to detailed microscopic examination, with the extraordinary result that the supporters of both rival theories find that it can be interpreted so as to support their views. The Funafuti boring cannot be said to have settled the matter. I believe the verdict at the present

time of most zoologists and geologists would be that whereas Darwin's beautiful theory would certainly hold good for coral reefs growing on a sinking area, Murray's explanation, based upon observations and ascertained facts, probably applies to many of the "atolls" and "barrier reefs" of tropical seas.

But I have been led on to these more recent times by his paper of 1880. Let us now return to his work at the "Challenger" Office. During the last couple of years of Sir Wyville Thomson's life, when he was more or less of an invalid, Mr. John Murray (as he then was) came gradually to take over more and more the complete charge of affairs at the "Challenger" Office, including the distribution of the groups of animals to specialists and the editing of the volumes of reports. It was very fortunate for zoological science that such a man was on the staff, ready to take up and carry out to a successful issue the work that Sir Wyville Thomson was no longer able to continue. Murray brought to the task a complete knowledge of all that had to be done and how best to do it, along with an extraordinary amount of zeal and energy. During the years that followed, until the completion of the work, he seemed to be doing several men's work. He was in constant communication, both by correspondence and personal visits, with all the authors of Reports in various parts of Europe and America; he had frequent dealings with the Government departments concerned in the production of the work; and all the time he was also himself investigating some of the great general problems of Oceanography. It is difficult to imagine that any other man than John Murray could have carried through all this mass of detailed and difficult work and have produced the fifty thick 4to volumes within twenty years of the return of the expedition. About five of these large volumes are the result of Murray's own work. Along with Staff-Commander T. H. Tizard, the late Professor H. N. Moseley, and Mr. J. Y. Buchanan, he drew up the general "Narrative of the

Expedition"; along with the late Professor Renard he wrote the very important report upon the "Deep Sea Deposits" (1891), generally recognised as the authoritative work on the subject; and finally, at the conclusion of the series, he produced two volumes entitled "Summary of Results" (1894), which gives an elaborate historical account of our knowledge of the sea and the development of the science of Oceanography from the earliest times to the present day, and also, in addition to complete lists of all the organisms at all the "Challenger" Stations, includes a discussion of many important matters, geological as well as biological, relating to the origin of our present distribution of land and water and of the distribution of the marine fauna and flora of the globe.

It was characteristic of him to put forward, especially in these "Summary" volumes, views which were novel and even daring, which he believed he had evidence to support, but which a less courageous man might have kept back or expressed more cautiously. He always had the courage of his convictions. He admitted that he sometimes made mistakes, but held that the man who never made a mistake never made anything else. That was one of his *obiter dicta* which were flying about the "Challenger" Office, and stuck in my impressionable youth. Let me read you a passage from one of his many letters that I have and which refers to the kind of views he afterwards published in his "Summary." It is dated 13th September, 1894, and is evidently in answer to some question I had asked as to his views on the past history of life in the sea.

". . . I gave two papers to the R.S.E. and also said something about distribution at the British Association, but I have not yet published anything. I am now considering whether or not I will add a chapter to the last "Challenger" Volume, giving my views.

"I believe the continental areas are very permanent, and for instance Africa has separated marine faunas and floras

longer than the time when there was a very nearly similar fauna at both poles. However, the faunas of the sea are now arranged more according to zones of temperature than by Land Barriers. The tropics extend polewards as we go down in the geological formations till just before the Chalk there was a universally warm sea—from equator to poles and from top to bottom—say 80° F.—Coral reefs once flourished at the poles. These have now been driven to equatorial regions where the temperature has remained nearly the above. The animals which in the universal warm sea came to live in the mud at a little depth, remained behind when cooling of the poles commenced. These animals without pelagic free-swimming larvae also descended to the deep sea as the waters cooled. When the sea was all 70° or 80° F. the deep sea was not inhabited. Polar animals and deep sea animals have all a direct development (so also fresh water animals, also derived from the deeper part of the shore estuarine universal fauna).

"It is nonsense to suppose that while the earth was developing the sun has always been the same as now. It has been contracting. In Chalk times it had a diameter seen from the earth equal to an angle of 10° in the heavens. This would give all the heat and *light* that is necessary for a great Carboniferous forest at the poles.

"You can tell me how much of this is d——d nonsense.

"Yours sincerely,

"JOHN MURRAY.

"Fresh water fauna is much more archaic than deep sea."

One of the theories which he supported, and which is not now generally accepted, although he believed he had much evidence in favour of it from the "Challenger" results, was the theory of "Bipolarity," viz., that identical organisms were found in arctic and antarctic seas and not in intermediate waters, and that they represented the original marine fauna which at some earlier period of the earth's history inhabited

all the oceans. This bipolarity hypothesis has been vigorously controverted, and like some other theories in Science which have had to be abandoned, was most useful in its day as giving rise to much new investigation. A good deal of evidence against Murray's views on bipolarity has been accumulated as the result of recent antarctic expeditions.

But whether all his views are accepted or not, they are all very stimulating and useful, and have given rise to much investigation and discussion in the history of Oceanography. His five great volumes are a notable monument to his memory. They and the other "Challenger" Reports which he edited record collectively the greatest advance in the knowledge of our planet since the great geographical discoveries of the 15th and 16th centuries.

We must now go back to a couple of subsidiary expeditions (1880-82) for the purpose of investigating the very remarkable conditions of temperature and fauna in the Faroe Channel.

Carpenter and Wyville Thomson, during their preliminary investigations in the "Lightning" and "Porcupine," had found that the Faroe Channel, between Cape Wrath and the Faroe Isles, was abruptly divided into two regions under very different conditions—a "cold" and a "warm" area. The temperature of the water to a depth of 200 fathoms is much the same in the two areas; but in the cold area to the N.E. the temperature is about 34° F. at 250 fathoms, and about 30° at the bottom in 640 fathoms, while in the warm area which stretches S.W. from the line of demarcation the temperature is 47° F. at 250 fathoms, and 42° at the bottom in 600 fathoms. The warm area was found to have 216 species, while the cold had 217, and of these only 48 species were common to both. A consideration of the "Challenger" temperatures led to the conclusion that the cold and warm areas of the Faroe Channel must be separated by a very considerable submarine ridge rising to within 200 or 300 fathoms of the surface. Sir Wyville

Thomson induced the Admiralty to give the use of a surveying vessel for a few weeks for the purpose of sounding the Faroe Channel with a view of testing this opinion. That was the origin of the "Knight-Errant" expedition in the summer of 1880, conducted by Captain Tizard, R.N., and Mr. John Murray, under the general direction of Sir Wyville Thomson, who remained at Stornoway, in the Outer Hebrides, during the four traverses of the region in question. The results (*Proc. Roy. Soc. Edin.* for 1882, Vol. XI.) showed that a ridge rising to within 300 fathoms of the surface runs from the N.W. of Scotland by the Island of N. Rona to the southern end of the Faroe fishing bank.

This was followed, after the death of Sir Wyville Thomson, by a further expedition in H.M.S. "Triton," in the summer of 1882, again under Murray and Tizard, which was very fruitful of zoological results. The discovery of two very different assemblages of animals living on the two sides of the Wyville Thomson ridge—arctic forms to the North and Atlantic forms to the South—gives us a notable example of the effect of the environment on the distribution of marine forms of life. The results of the "Triton" expedition, written by a number of specialists, were published in the *Trans. Roy. Soc. Edin.* during the next few years—a time during which Murray came to occupy a more and more prominent position in the scientific world of the North. When we remember that his earlier fellow-workers and associates at the University were such men as Robertson Smith the theologian, Dittmar the chemist, Sir John Jackson the great contractor, and Robert Louis Stevenson; and his later friends, after the return of the "Challenger," were such men as Agassiz, Turner, Crum-Brown, Tait, Renard, Haeckel, Geikie, Blackie, Masson, Buchan, and Lord McLaren, we can understand the stimulating intellectual atmosphere he lived and worked in and to which he doubtless contributed as much as he received.

We now come to a period of great local scientific activity, when Murray exercised a notable influence in the University scientific circle and took a leading part in every new movement. He was a prominent member of the Royal Society of Edinburgh, and of the Scottish Meteorological and Geographical Societies, he helped to establish the Observatory on the summit of Ben Nevis, and in 1884, along with his friend Robert Irvine of Caroline Park, on the shores of the Firth of Forth, he acquired the lease of an old sandstone quarry at Granton into which the sea had burst some thirty years before, drowning the quarry and leaving it as a land-locked sheet of sheltered deep water which rose and fell with every tide. Here he moored a large canal barge, upon which he had built a house, divided into chemical and biological laboratories, and which, for obvious reasons, he named "The Ark." Two little Norwegian skiffs were attached to "The Ark," one for the chemists and the other for the biologists, and on the opening day Dr. Hugh Robert Mill and I were invited to name them. He called his "The Asymptote" and I named the other "Appendicularia." Murray ridiculed our pretentious names, and said that in a few days the one would probably be called "the Simmie," or "the Tottie," and the other "Dick."

This floating biological station, after some years' work at Granton, was towed through the Forth and Clyde Canal to Millport on the Cumbraes, and there it was beached and remains to this day as part of the Millport Biological Station. During the period when "The Ark" was at Granton, and later, Murray and Irvine turned out a good deal of joint work on the Chemistry of the secretion of carbonate of lime by marine organisms, on the solution of carbonate of lime by the carbon-dioxide in sea-water, and on the chemical changes taking place in muds and other deposits on the sea-bottom. But, after all, his chief scientific work at this time and for years afterwards was the joint investigation at the

"Challenger" Office, of the enormous series of deposits (said to be over 12,000) which he and the Abbé Renard had accumulated from many expeditions and all seas. When one entered the little laboratory on the top floor of 32, Queen Street, after penetrating the dense cloud of tobacco smoke, the first thing one heard, rather than saw, was John Murray issuing some order or announcing some result, the next was the figure of the portly Abbé waving a courteous greeting with his perpetual cigar. Then there were the two Assistants, Mr. F. Pearcey, who had himself, as a boy, taken part in the great expedition, and had been retained as Assistant Curator of the collections at the "Challenger" Office, and Mr. James Chumley, the Secretary. Murray and Renard were hard at work at the microscope or at chemical reactions in test tubes over Bunsen burners, Pearcey was preparing fresh samples to be examined and Chumley was noting down results. There has probably never been in recent years such a small laboratory so poorly equipped, which has turned out such epoch-making results. Everything absolutely essential was there, but nothing in the least extravagant. The place looked, with its plain boards and deal tables and sinks, more like an overcrowded scullery than an Oceanographic laboratory.

But even in his busiest years at the "Challenger" Office Murray never gave up wholly his work at sea. He was a good hand at "roughing it" and making the best of circumstances, and no one could have had a greater appreciation of the open-air life. The practical work that he did, more or less periodically all the year round, on the West Coast of Scotland from his little yacht "Medusa" is a good example of careful planning and resolute carrying out.

It seems that while working at the results of the "Challenger" and other deep-sea expeditions, it occurred to Murray that for the purpose of comparison a detailed examination of the physical and biological conditions in the

fjord-like sea-lochs of the West of Scotland might yield valuable information. He accordingly built a small steam yacht of about 38 tons, called the "Medusa," fitted up with all necessary apparatus for dredging and trawling and for taking deep-sea temperatures and other observations. This little vessel was, in fact, fully equipped for oceanographical investigations in the neighbourhood of land, and during the years 1884 to 1892 she was almost continuously engaged in exploring the deep sea-lochs of the Western Highlands. Various younger scientific men, such as Dr. W. E. Hoyle and Dr. H. R. Mill, were associated with Murray in this work. Considerable collections were made, some of which are now in the British Museum, and many scientific papers contributed to various journals have resulted from the periodic cruises of the "Medusa." One result was the discovery in the deeper waters of Loch Etive and Upper Loch Fyne of the remnants of an arctic fauna.

From time to time during these researches in the sea-lochs the "Medusa" penetrated to the fresh-water lochs, such as Loch Lochie and Loch Ness, which are united by the Caledonian Canal, and Murray was greatly impressed by the differences in the physical and biological conditions between the salt and the fresh water lochs. This observation seems to have led to another of Murray's scientific activities, namely, the bathymetrical survey of the fresh water lochs of Scotland, undertaken between the years 1897 and 1909. It was already known that, like some of the salt water fjords outside, certain of these fresh water lochs are of surprising depth. For example, 175 fathoms had been recorded by Buchanan in Loch Morar, and Murray subsequently running a line of soundings along this loch found at one spot a depth of 180 fathoms.

The survey was undertaken at first in collaboration with his young friend, Mr. Frederick P. Pullar, who was drowned in a gallant attempt to save the lives of others in a skating accident on Loch Airthrey in 1901. The results of the Lake

Survey were published in a series of six volumes (Edinburgh, 1910), edited by Sir John Murray and Mr. Lawrence Pullar, and dedicated to the memory of Mr. F. P. Pullar, who had done much to initiate and promote the investigation in its earlier stages.

The work dealt with the determination of the depths of the lakes and of the general form of the basins they occupy, along with observations in other branches of limnography from the topographical, geological, physical, chemical and biological points of view. Some important novel investigations, such as those on the temperature seiche and variations in the viscosity of the water with temperature, help to throw light on some oceanographical problems. In fact, the whole investigation, containing 60,000 soundings taken in 562 lakes, resulted in very substantial contributions to knowledge, and is probably the most complete account of the depths and other physical features of lakes that has been published in any country.

It cannot be said that Murray ever finished his work on the West Coast of Scotland, and I have evidence in a letter that he wrote to me late in life that he still thought of returning to the work. The passage is worth quoting, both for its scientific interest and for the kindly consideration which it shows. It is dated 20th May, 1913, less than a year before his death :—

" . . . I am seriously thinking of overhauling all the 'Medusa' work on the West Coast, and repeating a lot of these old observations for two years or more; then publishing a book on the lochs of the West Coast. Would that in any way interfere with your work? I am being pressed by the Clyde people to do something of the kind.

"Could I afford it at present, I would be off to the Pacific in a Diesel-engined ship!!" . . . . .

During the years when he was working at the "Challenger" results and subsequently, Murray published many papers in the *Geographical Journal* and in the *Scottish Geographical*

*Magazine* and elsewhere, which deal with world-wide questions in Oceanography or in Physical Geography, such as the annual rainfall of the globe and its relation to the discharge of rivers, the effects of winds on the distribution of temperature in lochs, the annual range of temperature in the surface waters of the ocean, and the temperature of the floor of the ocean, on the height of the land and the depth of the ocean (1888), and on the depths, temperatures and marine deposits of the South Pacific Ocean (1906).

In 1897 Dr. John Murray (as he then was) formally opened the present Biological Station at Millport and the associated Robertson Museum, and delivered an address on the marine biology of the Clyde district. He continued to take a lively interest in the affairs of this West Coast Biological Station, and frequently looked in there with scientific friends when on his cruises in the "Medusa." I recollect, for example, an occasion, when after dredging in Loch Fyne, we ran to Millport for the night, and the party included Canon Norman, old Dr. David Robertson, Haeckel and the late Mr. Isaac Thompson, of this Society. He frequently had foreign men of science as his guests, and was, I think, especially friendly with the Scandinavians, such as Nansen, Hjort, Otto Pettersson the Swede, and C. G. Joh. Petersen the Dane.

Murray's oceanographic work was not limited to any particular region or special series of problems, but was world-wide, both in extent and subject matter. He was a great traveller, and had probably personally explored more of the oceanic waters of the globe than any other man. He had ranged from Spitzbergen in the North to the Antarctic Ice-barrier, dredging, trawling, tow-netting and sampling the waters and bottom deposits in every possible way. Even when travelling as an ordinary passenger on a liner, he would engage emigrants in the steerage to pump water daily from the sea through his silk nets, or would arrange with a bath-steward

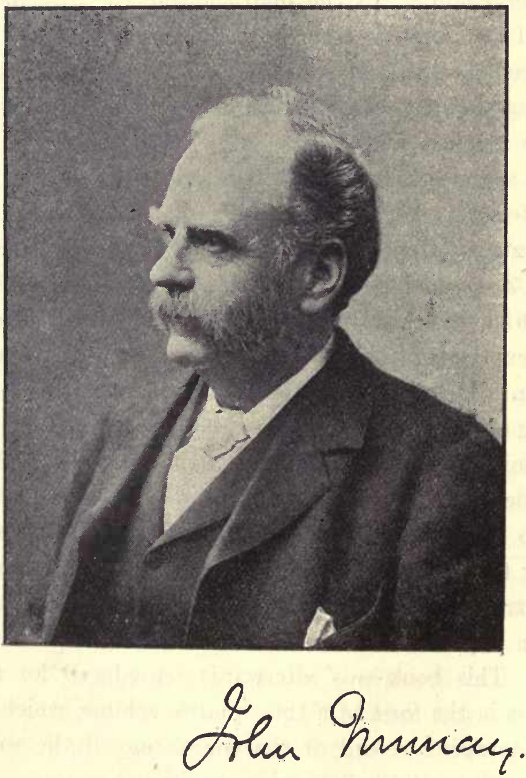
to let the sea-water tap run through his net day and night in order that he might have living plankton to examine.

Murray was not only an investigator of special problems, but we owe to him much synthetic work, in which he gathered together the results of many observations and put them in the form of short conclusions or statistical statements. Some of these were published in the form of useful maps and charts, such, for example, as the map showing the 57 "deeps," or parts of the ocean in which soundings of over 3,000 fathoms have been obtained. Most of these deeps (32) are in the Pacific, including the deepest soundings of all, which extend down to over six English miles.

At the meeting of the British Association held at Ipswich in September, 1895, a meeting of contributors to the "Challenger" Reports was held, at which the then President of the Zoological Section (W. A. Herdman) presided, and about fifty biologists or oceanographers, either attended or wrote expressing their concurrence in the objects of the meeting. It was then proposed and resolved "that this meeting of those who have taken part in the production of the 'Challenger' Reports agrees to signalise the completion of the series by offering congratulations in some appropriate form to Dr. John Murray." Eventually this congratulatory offering took the form of an address in an album, containing the portraits and autographs of all the "Challenger" workers, with an illuminated cover and dedicatory design by Walter Crane. This book was afterwards reproduced for the contributors in the form of a thin quarto volume, which forms a very interesting record of the completion of the work connected with the "Challenger" expedition.

Dr. Murray himself provided a very pleasing memento of the conclusion of the great work by having a handsome medal designed and struck, an example of which was presented to each of the authors of "Challenger" Reports. The medal

in a bronze alloy, measures 75 mm. in diameter, and shows on the obverse the head of Minerva encircled by Mermaids, a dolphin and Neptune holding in his left hand the trident, and in his right the Naturalists' dredge, with the legend "Voyage of H.M.S. 'Challenger,' 1872-76"; and on the reverse an armoured knight casting down his gauntlet in challenge to the waters—being the crest of H.M.S. "Challenger"—with




Portrait of Dr. John Murray, from the "Challenger" Album.

the legend, "Report on the scientific results of the 'Challenger' Expedition, 1886-95." The name of the recipient of the medal is engraved on the lower margin.

After Sir Wyville Thomson's death, when Murray came to be recognised by the scientific world as the moving spirit in connection with all the "Challenger" work, and especially when the great series of publications was completed, honours of all kinds came pouring in upon him—for which he probably cared little. He was an honorary doctor of many Universities—including our own here—he was awarded the "prix Cuvier" medal by the Paris Academy of Sciences, and he was created K.C.B. in 1898. He gave the Lowell lectures at Boston in 1899, and again in 1911. He was chief British Delegate at the International Congress for the Exploration of the Sea, at Stockholm, in 1899. He was President of the Geographical Section of the British Association in the same year; and it is an open secret that he might have been President of the Association had he been able to undertake it. He was approached no less than three times in connection with three different meetings (two of them overseas meetings, at which it was felt that a man of world-wide associations, such as Murray, would be singularly appropriate), but after some hesitation and careful consideration he felt that circumstances compelled him to decline the honour. Some of his letters to me, from which I quote a few passages, allude to these offers.

This is a letter from Mentone, on 1st April, 1904, referring to the first of these occasions:—

" . . . At first, I said it was impossible to alter our family and other arrangements so as to go to South Africa . . . . . To my astonishment my wife seems taken with the idea of going to the Cape, and says it is by no means impossible to alter our arrangements. I've promised to think over the matter for a week. I'll let you know definitely a day or two after I reach Edinburgh.

"I feel that you are predisposed to honour me, but I also feel I have given the Association very little of my attention: others have more claims on the honour. I don't care a bit

about it. If I consult my own feelings I would much rather have nothing to do with it. My wife suggests there may be some question of duty. Perhaps? I had not heard you had taken on the General Secretaryship." . . . . .

In a letter from Boston, U.S.A., he writes on 20th March, 1911:—

" . . . On Saturday I received your letter of the 3rd March. By same post had letters from Geikie and Bonney. Had I been at home I would of course have seen you before sending any reply, but I am not likely to be in England before June.

" . . . To-morrow I deliver the Agassiz address at Harvard. I came over for that address, but have been let in for the Lowell lectures (eight) and addresses here [Boston], Princeton, New York and Washington. We go to Washington next month . . . . .

" During the last two days I've had frequent deliberations with my wife and daughter, who are with me, and the only way out seemed to be to decline the nomination. For some time past I have been planning a cruise as far as the Pacific during 1912 and 1913, and I have made a good many business and domestic arrangements with that object in view. It must take place in these years or not at all, and if my health be good I cannot well withdraw.

" I know your enthusiastic nature and your too favourable opinion of my poor labours. I know you like to do me honour. For these reasons I very much regret the nature of the cables I have just sent off to you, Bonney and Geikie. I am anxious to do anything to assist the progress of Oceanography, but I fear my Presidentship of the British Association would not do much in that direction. However, it is very good and nice of you to say you think it would. I find many enthusiastic young workers here, and I believe there will likely be a ship fitted out for a deep sea expedition in 1912. They wish to consult

me at Washington and New York about this. Townsend is now away in the 'Albatross,' off the Pacific coast. They invited me to go with them, also to go to the Tortugas Station, where some very interesting work is going on." . . . . .

This further letter refers to the same occasion. It is from Washington, D.C., 19th April, 1911 :—

" . . . I duly received your letter of the 20th. I have not replied at once, especially as I had written to you when I sent off my cable, and I had also cabled and written to Bonney and Geikie. I have not changed my mind about the Presidency. I cannot see my way to accept. I am very sorry, for I would willingly do very much to please you and my other friends on the Council. I also believe that some scientific man less known locally would be more agreeable to the Dundee people.

" You will see from the enclosed cutting that they have been doing us much honour here. There was a dinner in our honour last week, about seventy-five scientific men here and their wives. The British Ambassador and his wife were present. Taft accepted, but sent an excuse at the last minute.

" . . . We go to Philadelphia to-morrow to meetings of Philadelphia Academy. Then to New York. Osborn is to have 14 millionaires to hear me at the Museum as to what they should do for the study of the Ocean ! ! May it have some effect !

" On the 26th we start for the West to see rocks and mines in Nevada. We sail from Boston on the 30th May.

" With my very best thanks to you for all your endeavours to honour me, and to cultivate an interest in Oceanography."

The following letter of 12th November, 1912, refers to the final occasion. He was killed before the meeting in question took place :—

" . . . . I shall not refuse at once. I'll consult with my wife. All the same I do not think it is the sort of thing for a man over seventy. I'm very well just now—have been for

the past three months shooting over the moors nearly every day! Some people say even that I am a wonder! but who can tell what I'll be like in two years. Men over seventy years are likely to break down, then what a nuisance I would be to everyone!

"I would, of course, appreciate the honour, but honours are not worth much to an old man. The only question would be, a real service to Science, and would it be a duty. At my age it can hardly be a duty. I have no message to give to the world!! I honestly think some young scientific man would do the trick very much better. I'll consider it. I'll be in London, Piccadilly Hotel, the first ten days of December, and could perhaps see you.

"I really very much appreciate your desire to honour me. It is really very good of you. It is not quite out of the possible that I may be in the Pacific in 1914 in a boat of my own. I would have been there now had the cost not been much greater than I, at first, calculated."

At the inauguration of the new Zoological Laboratories of the University of Liverpool in November, 1905, Sir John Murray was one of the honoured guests of the University, and after the formal opening by the Earl of Onslow, Sir John gave a short address upon Oceanography, the first lecture to be delivered in the Zoology lecture theatre of the University. A few years later, in 1907, the University conferred upon him the Honorary degree of Doctor of Science.

We now come to Sir John Murray's last great scientific expedition—a four months' cruise in the North Atlantic, in the summer of 1910—a very notable achievement for a man in his seventieth year. The investigating steamer "Michael Sars," was built by the Norwegian Government in 1900, on the lines of a large high-class trawler of about 226 tons, but specially fitted out for scientific work under the direction of

Murray's friend, Dr. Johan Hjort. At Murray's request this vessel was lent, with her crew and equipment, by the Norwegian Government for the North Atlantic cruise, Sir John Murray undertaking to pay all the expenses. The scientific reports on the Expedition will be published in a series of volumes by the Bergen Museum; but the more general results have appeared in popular form in a volume entitled, "The Depths of the Ocean" (Macmillan, 1912), by Murray and Hjort, with contributions by several other naturalists, which gives a condensed account of the modern science of Oceanography, with special chapters on the latest discoveries, based largely upon the experiences of this North Atlantic cruise taken along with the previous cruises of the "Michael Sars" in the Norwegian Seas.

Amongst noteworthy matters that are discussed in this volume we find:—

(1) Methods of plankton collecting, including the towing of as many as 10 large horizontal nets, at various depths, simultaneously. The pelagic plants collected, either in the nets or by centrifuging the water, are discussed in a notable chapter by Gran.

(2) The "Mud-line," a favourite subject with Murray, as being the great feeding-ground of the ocean. He places it at an average depth of 100 fathoms, on the edge of the "Continental-shelf," at the top of the "Continental-slope," which descends more or less precipitately to the floor of the Atlantic at an average depth of 2,000 fathoms. We know from Murray's careful estimations that, if all the elevations of the globe were filled into the depressions, we should have a smooth sphere covered by an ocean 1,450 fathoms deep. The floor of this ocean is the "mean sphere level."

(3) Dr. Helland-Hansen, the physicist on board the "Michael Sars," had devised a new form of photometer, which registered light as far down as 500 fms. in the Sargasso Sea. At between 800 and 900 fms., however, no trace of light

was registered on the photographic plates, even after two hours' exposure. The observations show that light in considerable quantity penetrates to a depth of at least 1,000 metres, which is much deeper than had been previously supposed. It was shown that the red rays of light are those that disappear first and the ultra violet are those that penetrate most deeply.

(4) A special study was made on the "Michael Sars" of the characteristic colour of the fishes in various zones of depth. In the superficial layers of the ocean small colourless or transparent forms abound, forming a part of the well-known pelagic fauna. Below this, at an average depth of about 200 fms., are found fishes of a silvery and greyish hue, along with red-coloured Crustaceans. At depths of from 500 fms. downwards black fishes make their appearance, still associated with red Crustaceans and other strongly coloured red, brown, or black Invertebrates. This chapter is illustrated by some beautiful coloured plates of the fishes.

(5) Lastly, the "Michael Sars" got important evidence in support of the view that the fresh-water eel spawns South of the Azores, and that the larvae are carried by currents back to the coasts of North-west Europe.

In 1913 Murray published in the Home University Library a small book of about 250 pages, entitled "The Ocean, a general account of the Science of the Sea," which is undoubtedly the most concise and accurate and, so far as is possible within its small compass, complete account that has yet appeared of all that pertains to the scientific investigation of the sea. It is written in simple language for the general reader, and is probably the best introduction to Oceanography that can be recommended to the junior student or the intelligent non-specialist enquirer who desires information merely as a matter of general culture. It deals with the history, methods and instruments of marine research, the depths and physical characters of the Ocean, the circulation of the waters, life in

the Ocean, submarine deposits, and finally the nature and relations of the various "Geospheres" that constitute the globe. Coloured maps and plates illustrate depths, salinities, temperatures, currents, deposits and many of the characteristic plants and animals of the plankton and of the "oozes." As Murray's final contribution to Science it is an appropriate summary of his life-work, and will do much to spread the knowledge of his discoveries and to make his name widely known amongst intelligent readers of popular works on Science.

If I try now to give you a personal impression of John Murray as I remember him in earlier life, I picture him as a short, thick-set, broad shouldered man, with a finely-shaped head and very forcible-looking blue eyes, under rather shaggy eye-brows. His hair was fair, somewhat reddish on the whiskers and moustache. Later in life, when his hair was turning white, he wore a closely-clipped beard. It was a strong, determined-looking face, with those arresting eyes, making him a noticeable and dominant figure in any assembly. But the eyes could dance with fun on occasions, and his good Scots tongue was kindly as well as outspoken. He remained sturdy and energetic to the last, although he was 73 years of age a few days before the motor accident in which he was instantaneously killed on March 16th, 1914.

John Murray was a man of upright character and of downright speech. He was apt to tell you what he thought of you, or anyone else, in plain and emphatic language without fear or favour. Some people of more conventional habits may have been shocked or offended at times; but the better one knew him the more one came to appreciate and admire his transparent honesty of thought and speech, his most uncommon "common-sense," his purity of motive and directness of purpose and his genuine kindness and goodheartedness, especially to all the young scientific men who worked with

or under him and whom he in large measure trained. He was absolutely free from all guile and humbug of any kind, and had no sympathy with intrigue or vacillation.

I may appropriately conclude this short account of John Murray's life and work with a few sentences quoted from an appreciation (*Nature*, 1914, p. 89) by his old friend, and former teacher, Sir Archibald Geikie:—

"Sir John Murray's devotion to science and his sagacity in following out the branches of inquiry which he resolved to pursue, were not more conspicuous than his warm sympathy with every line of investigation that seemed to promise further discoveries. He was an eminently broad-minded naturalist to whom the whole wide domain of Nature was of interest. Full of originality and suggestiveness, he not only struck out into new paths for himself, but pointed them out to others, especially to younger men, whom he encouraged and assisted. His genial nature, his sense of humour, his generous helpfulness, and a certain delightful boyishness which he retained to the last endeared him to a wide circle of friends who will long miss his kindly and cheery presence."

APPENDIX B.

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## THE LIVERPOOL MARINE BIOLOGY COMMITTEE (1917).

HIS EXCELLENCY THE RIGHT HON. LORD RAGLAN, Lieut.-Governor of the Isle of Man.

RT. HON. SIR JOHN BRUNNER, BART.

PROF. R. J. HARVEY GIBSON, M.A., Liverpool.

MR. W. J. HALLS, Liverpool.

PROF. W. A. HERDMAN, D.Sc., F.R.S., F.L.S., Liverpool. Chairman of the L.M.B.C., and Hon. Director of the Biological Station.

MR. P. M. C. KERMODE, Ramsey, Isle of Man.

PROF. BENJAMIN MOORE, F.R.S., London.

SIR CHARLES PETRIE, Liverpool.

MR. E. THOMPSON, Liverpool, Hon. Treasurer.

MR. A. O. WALKER, F.L.S., J.P., formerly of Chester.

MR. ARNOLD T. WATSON, F.L.S., Sheffield.

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Curator of the Station—MR. H. C. CHADWICK, A.L.S.

Assistant—MR. T. N. CREGEEN.

## CONSTITUTION OF THE L.M.B.C.

(Established March, 1885.)

I.—The Object of the L.M.B.C. is to investigate the Marine Fauna and Flora (and any related subjects such as submarine geology and the physical condition of the water) of Liverpool Bay and the neighbouring parts of the Irish Sea and, if practicable, to establish and maintain a Biological Station on some convenient part of the coast.

II.—The Committee shall consist of not more than 12 and not less than 10 members, of whom 3 shall form a quorum; and a meeting shall be called at least once a year for the purpose of arranging the Annual Report, passing the Treasurer's accounts, and transacting any other necessary business.

III.—During the year the Affairs of the Committee shall be conducted by an Hon. Director, who shall be Chairman of the Committee, and an Hon. Treasurer, both of whom shall be appointed at the Annual Meeting, and shall be eligible for re-election.

IV.—Any Vacancies on the Committee, caused by death or resignation, shall be filled by the election at the Annual Meeting of those who, by their work on the Marine Biology of the district, or by their sympathy with science, seem best fitted to help in advancing the work of the Committee.

V.—The Expenses of the investigations, of the publication of results, and of the maintenance of the Biological Station shall be defrayed by the Committee, who, for this purpose, shall ask for subscriptions or donations from the public, and for grants from scientific funds.

VI.—The Biological Station shall be used primarily for the Exploring work of the Committee, and the Specimens collected shall, so far as is necessary, be placed in the first

instance at the disposal of the members of the Committee and other specialists who are reporting upon groups of organisms; work places in the Biological Station may, however, be rented by the week, month, or year to students and others, and duplicate specimens which, in the opinion of the Committee, can be spared may be sold to museums and laboratories.

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## LIVERPOOL MARINE BIOLOGICAL STATION AT PORT ERIN.

### General Regulations.

I.—This Biological Station is under the control of the Liverpool Marine Biology Committee, the executive of which consists of the Hon. Director (Prof. Herdman, F.R.S.) and the Hon. Treasurer (Mr. E. Thompson).

II.—In the absence of the Director, and of all other members of the Committee, the Station is under the temporary control of the Resident Curator (Mr. H. C. Chadwick), who will keep the keys, and will decide, in the event of any difficulty, which places are to be occupied by workers, and how the tanks, boats, collecting apparatus, &c., are to be employed.

III.—The Resident Curator will be ready at all reasonable hours and within reasonable limits to give assistance to workers at the Station, and to do his best to supply them with material for their investigations.

IV.—Visitors will be admitted, on payment of a small specified charge, at fixed hours, to see the Aquarium and Museum adjoining the Station. Occasional public lectures are given in the Institution by members of the Committee.

V.—Those who are entitled to work in the Station, when

there is room, and after formal application to the Director, are :—(1) Annual Subscribers of one guinea or upwards to the funds (each guinea subscribed entitling to the use of a work place for three weeks), and (2) others who are not annual subscribers, but who pay the Treasurer 10s. per week for the accommodation and privileges. Institutions, such as Universities and Museums, may become subscribers in order that a work place may be at the disposal of their students or staff for a certain period annually; a subscription of two guineas will secure a work place for six weeks in the year, a subscription of five guineas for four months, and a subscription of £10 for the whole year.

VI.—Each worker is entitled to a work place opposite a window in the Laboratory, and may make use of the microscopes and other apparatus, and of the boats, dredges, tow-nets, &c., so far as is compatible with the claims of other workers, and with the routine work of the Station.

VII.—Each worker will be allowed to use one pint of methylated spirit per week free. Any further amount required must be paid for. All dishes, jars, bottles, tubes, and other glass may be used freely, but must not be taken away from the Laboratory. Workers desirous of making, preserving, or taking away collections of marine animals and plants, can make special arrangements with the Director or Treasurer in regard to bottles and preservatives. Although workers in the Station are free to make their own collections at Port Erin, it must be clearly understood that (as in other Biological Stations) no specimens must be taken for such purposes from the Laboratory stock, nor from the Aquarium tanks, nor from the steam-boat dredging expeditions, as these specimens are the property of the Committee. The specimens in the Laboratory stock are preserved for sale, the animals in the tanks are for the instruction of visitors to the Aquarium, and as all the expenses of steam-boat dredging expeditions are defrayed by the Committee, the

specimens obtained on these occasions must be retained by the Committee (*a*) for the use of the specialists working at the Fauna of Liverpool Bay, (*b*) to replenish the tanks, and (*c*) to add to the stock of duplicate animals for sale from the Laboratory.

VIII.—Each worker at the Station is expected to prepare a short report upon his work—not necessarily for publication—to be forwarded to Prof. Herdman before the end of the year for notice, if desirable, in the Annual Report.

IX.—All subscriptions, payments, and other communications relating to finance, should be sent to the Hon. Treasurer. Applications for permission to work at the Station, or for specimens, or any communications in regard to the scientific work should be made to Professor Herdman, F.R.S., University, Liverpool.

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## Memoranda for Students and Others working at the Port Erin Biological Station.

Post-graduate students and others carrying on research will be accommodated in the small work-rooms of the ground floor laboratory and in those on the upper floor of the new research wing. Some of these little rooms have space for two persons who are working together, but researchers who require more space for apparatus or experiments will, so far as the accommodation allows, be given rooms to themselves.

Undergraduate students working as members of a class will occupy the large laboratory on the upper floor or the front museum gallery, and it is very desirable that these students should keep to regular hours of work. As a rule, it is not expected that they should devote the whole of each day to work in the laboratory, but should rather, when tides are suitable, spend a portion at least of either forenoon or afternoon on the sea-shore collecting and observing.

Occasional collecting expeditions are arranged under guidance either on the sea-shore or out at sea, and all undergraduate workers should make a point of taking part in these.

It is desirable that students should also occasionally take plankton gatherings in the bay for examination in the living state, and boats are provided for this purpose at the expense of the Biological Station to a reasonable extent. Students desiring to obtain a boat for such a purpose must apply to the Curator at the Laboratory for a boat voucher. Boats for pleasure trips are not supplied by the Biological Station, but must be provided by those who desire them at their own expense.

Students requiring any apparatus, glass-ware or chemicals from the store-room must apply to the Curator. Although the Committee keep a few microscopes at the Biological Station, these are mainly required for the use of the staff or for general demonstration purposes. Students are therefore strongly advised, especially during University vacations, not to rely upon being able to obtain a suitable microscope, but ought if possible to bring their own instruments.

Students are advised to provide themselves upon arrival with the "Guide to the Aquarium" (price 3d.), and should each also buy a copy of the set of Local Maps (price 2d.) upon which to insert their faunistic records and other notes.

Occasional evening meetings in the Biological Station for lecture and demonstration purposes will be arranged from time to time. Apart from these, it is generally not advisable that students should come back to work in the laboratory in the evening; and in all cases all lights will be put out and doors locked at 10 p.m. When the institution is closed, the key can be obtained, by those who have a valid reason for entering the building, only on personal application to Mr. Chadwick, the Curator, at 3, Rowany Terrace.

## REGULATIONS OF THE EDWARD FORBES EXHIBITION.

[Extracted from the *Calendar* of the University of Liverpool for the Session 1915-16, p. 438.]

" EDWARD FORBES EXHIBITION.

" Founded in the year 1915 by Professor W. A. Herdman, D.Sc., F.R.S., to commemorate the late Edward Forbes, the eminent Manx Naturalist (1815-1854), Professor of Natural History in the University of Edinburgh, and a pioneer in Oceanographical research.

The Regulations are as follows :—

(1) The interest of the capital, £100, shall be applied to establish an Exhibition which shall be awarded annually.

(2) The Exhibitioner shall be a post graduate student of the University of Liverpool, or, in default of such, a post-graduate student of another University, qualified and willing to carry on researches in the Manx seas at the Liverpool Marine Biological Station at Port Erin, in continuation of the Marine Biological work in which Edward Forbes was a pioneer.

(3) Candidates must apply in writing to the Registrar, on or before 1st February.

(4) Nomination to the Exhibition shall be made by the Faculty of Science on the recommendation of the Professor of Zoology.

(5) The plan of work proposed by the Exhibitioner shall be subject to the approval of the Professor of Zoology.

(6) Should no award be made in any year, the income shall be either added to the capital of the fund, or shall be applied in such a way as the Council, on the recommendation of the Faculty of Science, may determine.

(7) The Council shall have power to amend the foregoing Regulations, with the consent of the donor, during his lifetime, and afterwards absolutely; provided, however, that the name of Edward Forbes shall always be associated with the Exhibition, and that the capital and interest of the fund shall always be used to promote the study of Marine Biology."

### Edward Forbes Exhibitioners.

| | |
|---|---|
| 1915 | Ruth C. Bamber, M.Sc. |
| 1916 | E. L. Gleave, M.Sc. |
| 1917 | C. M. P. Stafford, B.Sc. |

APPENDIX C.

## HON. TREASURER'S STATEMENT.

The Balance Sheet and List of Subscribers are shown on the following pages.

There is, unfortunately, a debit balance, due to the fact that the expenses have unavoidably increased and the receipts are rather less than previously. It is to be regretted also that the Board of Agriculture and Fisheries did not see their way this year to grant a further sum for research work. There is, however, still a balance in hand for this purpose, so this work will be carried on as usual next year. It is to be hoped that there will be increased support, either by special donations or by annual subscriptions, to enable the Committee to open up further fields of useful work and research, which are even more important now than they have ever been.

EDWIN THOMPSON,
Hon. Treasurer

25, Sefton Drive,
Liverpool. *December 13th*, 1917

## SUBSCRIBERS.

| | £ | s. | d. |
|---|---|---|---|
| Browne, Edward T., M.A., Anglefield, Berkhamsted, Herts. ... ... ... ... ... | 1 | 1 | 0 |
| Brunner, Mond & Co., Northwich... ... ... | 1 | 1 | 0 |
| Brunner, Rt. Hon. Sir John, Bart., Silverlands, Chertsey ... ... ... ... ... | 5 | 0 | 0 |
| Brunner, J. F. L., M.P., 43, Harrington Gardens, London, S.W. ... ... ... ... ... | 2 | 2 | 0 |
| Brunner, Roscoe, Belmont Hall, Northwich ... | 1 | 1 | 0 |
| Clubb, Dr. J. A., Public Museums, Liverpool ... | 0 | 10 | 6 |
| Dale, Sir Alfred, University, Liverpool ... ... | 1 | 1 | 0 |
| Dixon-Nuttall, F. R., J.P., F.R.M.S., Prescot ... | 2 | 2 | 0 |
| Gibson, Prof. R. J. Harvey, The University, Liverpool ... ... ... ... ... | 1 | 1 | 0 |
| Graveley, F. H., Indian Museum, Calcutta ... | 0 | 10 | 6 |
| Halls, W. J., 35, Lord-street, Liverpool ... ... | 1 | 1 | 0 |
| Herdman, Prof., F.R.S., University, Liverpool ... | 2 | 2 | 0 |
| Hewitt, David B., J.P., Northwich ... ... | 1 | 1 | 0 |
| Hickson, Prof., F.R.S., University, Manchester ... | 1 | 1 | 0 |
| Holt, Dr. Alfred, Dowsefield, Allerton ... ... | 1 | 0 | 0 |
| Holt, Mrs., Sudley, Mossley Hill, Liverpool ... | 2 | 2 | 0 |
| Isle of Man Natural History Society ... ... | 2 | 2 | 0 |
| Jarmay, Gustav, Hartford, Cheshire ... ... | 1 | 1 | 0 |
| Livingston, Charles, 16, Brunswick-st., Liverpool | 1 | 1 | 0 |
| Manchester Microscopical Society... ... .. | 1 | 1 | 0 |
| Meade-King, R. R., Tower Buildings, Liverpool... | 0 | 10 | 0 |
| Mond, R., Sevenoaks, Kent... ... ... ... | 5 | 0 | 0 |
| Monks, F. W., Warrington... ... ... ... | 2 | 2 | 0 |
| Muspratt, Dr. E. K., Seaforth Hall, Liverpool ... | 5 | 0 | 0 |
| O'Connell, Dr. J. H., Dunloe, Heathfield-road, Liverpool ... ... ... ... ... | 1 | 1 | 0 |
| Forward ... ... | £42 | 15 | 0 |

| | £ | s. | d. |
|---|---|---|---|
| Forward... ... | 42 | 15 | 0 |
| Petrie, Sir Charles, Ivy Lodge, Aigburth, Liverpool | 1 | 1 | 0 |
| Rathbone, Miss May, Backwood, Neston ... ... | 1 | 1 | 0 |
| Rathbone, Mrs., Green Bank, Allerton, Liverpool | 1 | 0 | 0 |
| Roberts, Mrs. Isaac, Thomery, S. et M., France ... | 1 | 1 | 0 |
| Robinson, Miss M. E., Holmfield, Aigburth, L'pool | 1 | 0 | 0 |
| Smith, A. T., 43, Castle-street, Liverpool... ... | 1 | 1 | 0 |
| Tate, Sir W. H., Woolton, Liverpool ... ... | 2 | 2 | 0 |
| Thompson, Edwin, 25, Sefton Drive, Liverpool ... | 1 | 1 | 0 |
| Thornely, Miss, Nunclose, Grassendale ... ... | 0 | 10 | 0 |
| Thornely, Miss L. R., Nunclose, Grassendale ... | 2 | 2 | 0 |
| Toll, J. M., 49, Newsham-drive, Liverpool ... | 1 | 1 | 0 |
| Walker, Alfred O., Ulcombe Place, Maidstone ... | 3 | 3 | 0 |
| Ward, Dr. Francis, 20, Park Road, Ipswich ... | 2 | 2 | 0 |
| Watson, A. T., Tapton-crescent Road, Sheffield ... | 1 | 1 | 0 |
| Whitley, Edward, The Holt, Linton-road, Oxford | 2 | 2 | 0 |
| Yates, Harry, 75, Shudehill, Manchester ... ... | 1 | 1 | 0 |
| | £65 | 4 | 0 |
| *Deduct* Subscriptions still unpaid *less* old Subscriptions received ... ... ... | 6 | 6 | 0 |
| | £58 | 18 | 0 |

SUBSCRIPTIONS FOR THE HIRE OF "WORK-TABLES."

| | | | |
|---|---|---|---|
| Victoria University, Manchester ... ... ... | £10 | 0 | 0 |
| University, Liverpool ... ... ... ... | 10 | 0 | 0 |
| University, Birmingham ... ... ... .. | 10 | 0 | 0 |
| | £30 | 0 | 0 |

# THE LIVERPOOL MARINE BIOLOGY COMMITTEE.

**Dr.** IN ACCOUNT WITH EDWIN THOMPSON, HON. TREASURER. **Cr.**

| 1917. | £ | s. | d. |
|---|---|---|---|
| To Printing and Stationery | 22 | 7 | 4 |
| ,, Boat Hire | 4 | 13 | 0 |
| ,, Books, Apparatus and Supplies at Port Erin Biological Station | 14 | 6 | 0 |
| ,, Postage, Carriage, &c. | 4 | 2 | 11 |
| ,, Salary—Share of Curator's | 85 | 0 | 0 |
| ,, ,, ,, Assistant's | 50 | 1 | 0 |
| ,, Sundries | 3 | 14 | 4 |
| | £184 | 4 | 7 |

| 1917. | £ | s. | d. |
|---|---|---|---|
| By Balance in hand, December, 1916 | 10 | 10 | 4 |
| ,, Subscriptions and Donations received | 58 | 18 | 0 |
| ,, Amount received from Universities for hire of "Work Tables" | 30 | 0 | 0 |
| ,, Interest on British Association (1896) Fund ... | 30 | 0 | 0 |
| ,, Sale of Guides and Post Cards | 2 | 11 | 1 |
| ,, ,, Specimens, &c. | 15 | 18 | 11 |
| ,, Bank Interest | 17 | 14 | 4 |
| ,, Balance due Treasurer, December, 1917 | 18 | 11 | 11 |
| | £184 | 4 | 7 |

Endowed Invested Fund:—
British Workman's Public House Co. 90 Shares
£1 each fully paid.

| | £ | s. | d. |
|---|---|---|---|
| Memoir Fund—Balance, as at December, 1916 | £185 | 0 | 1 |
| Extension Fund :—Balance, as at December, 1916 | £37 | 4 | 9 |
| Board of Agriculture and Fisheries Account— | | | |
| Balance December, 1916 | 242 | 13 | 0 |
| Fisheries Research Work Expenditure | 56 | 4 | 1 |
| | £186 | 8 | 11 |

EDWIN THOMPSON,
HON. TREASURER.

*Audited and found correct,*
COOK & LEATHER,
Chartered Accountants.

LIVERPOOL, *December 13th, 1917.*

# REPORT ON THE INVESTIGATIONS CARRIED ON DURING 1917 IN CONNECTION WITH THE LANCASHIRE SEA-FISHERIES LABORATORY AT THE UNIVERSITY OF LIVERPOOL, AND THE SEA-FISH HATCHERY AT PIEL, NEAR BARROW.

EDITED BY

PROFESSOR W. A. HERDMAN, F.R.S.,

Honorary Director of the Scientific Work.

CONTENTS.



## INTRODUCTION.

Shortly after the publication of last year's Report in March, 1917, it became evident that some of Dr. Johnstone's results in regard to the analysis and the resulting food value of fish, which were published in brief form in that Report, were not in accord with statements made authoritatively elsewhere by some other scientific men. Under these circumstances, knowing the care and skill with which Dr. Johnstone's work had been done, I urged him to continue his investigations for another year and to repeat the analyses in order that we might publish the reconsidered results in fuller detail in the present Report.

In view of the importance at the present time, in the interests of the public welfare, of any such contributions as this to a knowledge of correct food values, I had no hesitation in recommending to the Chairman that I should be authorised to lay before the Committee for publication a somewhat longer and more detailed Report than those of the last couple of years.

Dr. Johnstone's investigations have shown that it is impossible to put down definite figures for the dietetic value of "the herring," or herrings in general. In order that figures may have any meaning, it is necessary to state the kind of herring and when and where it was caught. For example, the valuable fatty material in the flesh of the herring, derived from its rich crustacean food, may apparently vary, according to the kind of herring and the time of year, from about 2% to about 40%. In the analysis of an average herring, pickled when in good condition during the summer fishery, this fat would amount to about 22%, the proteid contents might be 21%, and the ash (including the salt) nearly 10%, leaving about 47% for water and minute traces of other things. But these figures would not apply to other herrings caught at other times of the year. For fuller details on this very important subject and other valuable information on the dietetic value of fish, I refer the Committee and all others interested in this important branch of the national food supply to the statement of results given in Dr. Johnstone's article at p. 85.

Dr. Johnstone is now extending his work to other allied fish, and the natural application of his results to a consideration of the best methods of preserving our periodic large fisheries in such a way as to secure the best food values and render them available for the public use.

Dr. Johnstone's statistical article on the plaice fishery of the last quarter of a century gives only a brief and preliminary survey of the full and detailed report on the subject which he has prepared and which we hope to print on some future occasion. The demonstration of the variations in the numbers of plaice caught, over periods of years, is very interesting, and apparently this natural periodicity in the plaice fisheries has not been affected by the artificial change in conditions resulting from the circumstances of the War.

## Work at Piel.

Mr. Scott has supplied the customary report on the events of the year at our Piel Hatchery, and has given a brief account of those investigations which it has been possible for him to carry on under the War restrictions which are imposed upon his work. His remarks and statistics in connection with the Periwinkle fishery are of special interest.

## Plankton Investigations.

We have been able to carry on during the past year the periodic collection of plankton samples in Port Erin Bay, and these samples have been investigated in detail by Mr. Scott and treated statistically by Miss Lewis in the usual manner. The detailed statements, tables and curves for the various dominant groups of plankton organisms are kept in reserve for publication in detail some time in the future. It may suffice now to state that, as in the previous year, I was able during 1917 to take a series of additional gatherings from the motor boat during the two critical periods—spring (April) and autumn (August and September)—when the Diatoms and Copepoda are respectively present in greatest abundance. These gatherings show that the vernal maximum in 1917 extended from the middle of April to the middle of May, while the Copepoda reached their maximum in August.

One conclusion that is becoming clear from our accumulated observations of the last ten years is the surprisingly small number of organisms that make up the bulk of the plankton. Our food from the sea depends in great measure ultimately upon some half-dozen species of Copepoda and about the same number of Diatoms.

W. A. HERDMAN.

Fisheries Laboratory,
University of Liverpool,
*March 19th*, 1918.

# REPORT ON THE WORK AT PIEL.

By Andrew Scott, A.L.S.

## I. Distribution of Fish Eggs in the Plankton.

This investigation was continued in 1917, and 387 samples of the surface organisms from Port Erin Bay were examined for fish eggs. Nothing noteworthy has to be recorded in the seasonal distribution compared with any of the previous years. The records will be useful, however, when the complete analysis of the whole investigation is dealt with.

## II. Oil in Copepoda (*Temora*).

On July 10th, 1917, at the height of the Manx herring fishery, Professor Herdman's attention was directed to large bright red patches at the surface of the sea which had been noticed by the fishermen for some days near the Calf of Man. Samples were secured by dipping a half-gallon jar into the mass and pouring the catch through a fine net. When the material thus collected was examined it was found to consist of an almost entirely pure catch of the Copepod *Temora longicornis*. An estimation was made of the number present in the sample submitted for examination, by the method used by us in our quantitative plankton investigation. From the results obtained it was calculated that the half-gallon jar contained at least 132,000 *Temora* and 2 *Calanus*. Part of the sample was afterwards mixed with a little water and poured into a measuring jar. It was allowed to settle to a final level and read off. The volume of Copepoda was 9 cubic centimetres. The jar was then shaken up and the contents poured into a filter paper, which separated the Copepoda from the water. The small mass of Copepoda thus obtained was transferred to dry filter

paper to remove any surplus moisture present. It was next transferred to a dried weighed filter thimble and weighed. The nett weight of the moist *Temora* was found to be 2·688 grammes. The thimble filter and Copepoda were then dried to a constant weight in a water bath which was kept boiling. The nett weight of dry *Temora* was 0·925 gramme. The oil was extracted by means of the Soxhlet apparatus and carbon tetrachloride into a weighed flask. From the results obtained it was calculated that 100 grammes of dry *Temora* substance contained 2·47 grammes of oil. The oil while warm was a pale yellow liquid, but on completely cooling it became a solid somewhat crystalline mass. The quantity of *Temora* used was of course much too small for an accurate investigation, which should have been repeated for comparison. The result must therefore only be regarded as approximate. It is very rarely that sufficiently large samples of a single species of Copepoda are found in the Irish Sea to enable one to determine the amount of oil. The richness of the plankton plays a very important part in a successful herring fishery. No doubt much of the fat which makes the Manx summer herring so valuable is derived from the Copepoda captured by the fish as it swims through the water.

## III. Food of Port Erin Herring.

In the report for 1916 (page 9) I gave the results of the examination of herring stomachs from a sample of fish landed at Port-Erin on July 5th, 1916. Professor Herdman sent me another stomach from a sample of herring landed at Port Erin on July 31st, 1917. This stomach was carefully opened up. The contents were mixed with a little water and transferred to a measuring jar. After allowing the solid matter to settle for some time its height was read off and was found to measure 5 cubic centimetres. A detailed examination was then made

and it was found that the contents of the herring stomach consisted almost entirely of partially digested *Temora* with about half a dozen crab zoea in a fragmentary condition. A count of the more perfect *Temora* was made and 975 specimens found. It is evident that the herring caught at the end of July, 1917, had been feeding on the red patches described above. The very fresh condition of some of the *Temora* in the stomach indicated that they had been recently eaten, and it is probable that the visitation of such large numbers of *Temora* had lasted for nearly a month. The herring does not appear to make any selection of species, and simply feeds upon whatever crustacea are present around it as it swims along. The major part of the food in the stomachs examined in July, 1916, consisted of *Calanus finmarchicus* and larval Schizopoda.

### IV. Morecambe Sprat Fishery.

The season 1917-1918 (October to February) was a partial failure. This was not so much due to the scarcity of the fish as, in the main, to the bad weather. The prevailing winds were from the south and south-west, and frequently reached the strength of a gale. This kind of weather is quite unfavourable to a successful prosecution of the sprat fishery. It sets up heavy seas which prevent the use of the stow-net from the anchored boats. The system was fully described in the report for 1915. The conditions most favourable for a successful sprat fishery at Morecambe are light easterly winds and very little sea. The quantity of sprats caught was slightly over 400 tons. The quantity caught in 1916-1917 was 740 tons. Owing to the higher prices that were obtained the money value of the sprats caught in 1917-1918 was nearly double the amount obtained for the much greater catch in 1916-1917. Maximum retail prices for most kinds of fish came into force on January 23rd, 1918. The maximum price allowed for sprats is 6d. per

lb., and that has been the amount charged by the fishmongers in Barrow. The selling price prior to the fixed maximum was 4½d. per lb. The value of the sprats caught during February, 1918, according to the monthly returns of Sea Fisheries, England and Wales, published by the Board of Agriculture and Fisheries, was at the rate of 1½d. per lb. The value during the corresponding period in 1917 was at the rate of 1d. per lb., and the retail price to the public in Barrow at the same time was 4d. per lb. The fixing of a maximum price for sprats seems so far to have added ½d. per lb. to the income of the fishermen, for which the public pay 2d.

Samples of the catches were sent fortnightly by Mr. Edward Gardner for examination while the fishery lasted. Owing to unavoidable postal delays, they were not always in good condition when received. The size of the fish varied from 145 millimetres long to 95 millimetres long. At the end of February the reproductive organs of fully 80% of the fish were nearly mature.

## V. Barrow Channel Mussels.

The Head Scar mussel bed in this channel was rather extensively exploited for a time by the local fishermen. The Medical Officer for Barrow eventually prohibited the sale in the local shops on the ground that they were unfit for food. He also notified the Medical Officer of other inland towns that mussels from Barrow should be regarded with suspicion and not used for food. This immediately put a stop to the trade, and no more mussels have been removed from the scar. The head scar is one of the beds which the late Dr. Bulstrode in his report "On Shellfish other than Oysters in relation to disease" (Thirty-ninth Annual Report of the Local Government Board 1909-10) regarded as seriously exposed to the risk of sewage contamination. The population of Barrow and Dalton at the

time the report was published was about 72,000. It is now fully 100,000. The main sewer outfall discharges on the foreshore some distance above the bed, and under certain conditions the mussels may be contaminated by the crude sewage. I understand arrangements are now being made to hold a public inquiry under the Public Health Shell-fish (Regulations) 1915, No. 125, at Barrow, and notices will be sent to all interested parties. The bed is at present well stocked with mussels which look to the naked eye in good condition. It is to be hoped that some plan will be adopted so that these mussels can be transplanted and rendered free from suspicion, as there was a large demand for them. There are areas not far from the bed where the topographical conditions seem favourable for the establishment of a cleaning tank similar to those at Aberdovey and Barmouth. It might be possible to get this done during the coming summer and have it in working order early in the next mussel season.

## VI. The Periwinkle Fishery.

This is one of the minor inshore fisheries of the Lancashire and Western Sea Fisheries District which appears to be capable of further development in the future. At the present moment it is suffering, in common with many other industries, from the depletion of its fishermen, and its value is much reduced. The majority of the men formerly engaged in periwinkle fishing have found employment in various large works, and there is a marked reduction in the quantity sent to the market now compared with pre-war figures. The fishery is carried on in only a few districts in the area where the conditions between tide marks are favourable. It is essential that the shore should be fairly rough with a plentiful supply of growing sea-weed. The periwinkle is a vegetarian and feeds upon the weed. The small boulders provide a firm foothold and shelter against

the action of storms. Sandy and muddy shores which are devoid of " scarry " ground are unfavourable for the production of periwinkles. The mean annual income from the sale of periwinkles collected by the fishermen in the area controlled by the Committee is nearly £700.

Piel, near Barrow-in-Furness, is one of the centres of the periwinkle industry. Fully one-third of the total annual quantity collected in the whole district is sent away from there. The area fished by the Piel fishermen is of considerable extent. It comprises the seaward limit of Barrow Channel and the western end of Roosebeck shore. The ground is never overfished at any time. The fluctuation in quantity from year to year shown by the accompanying Table is largely due to conditions of local trade prosperity. A certain number of the men are practically whole time fishermen. Others engage in it when employment is not obtainable in the works in the district. There are no restrictions of any kind, but the industry is mainly a seasonal one. The maximum supply is sent away between October and May. The normal number of periwinkle fishermen in pre-war times was eight. The mean annual quantity sent to the inland towns of Lancashire and to London, from the beginning of 1906 to the end of 1914, was nearly forty-eight tons. The income received by the men was nearly £240 a year. Previous to the war, the chief occupation during the summer months was ferrying visitors to Piel Island and back and taking fishing parties from various North Lancashire towns to catch codling, dabs, and mackerel on the adjacent fishing grounds. The restrictions on boating, etc., which were instituted by the Naval and Military Authorities immediately on the declaration of war, put an end to the usual summer occupation of the majority of the periwinkle fishermen. Half of them went into the munition works, and one found employment at sea on the examination vessel. The three remaining men are considerably over military age. They are carrying on with a fair amount of success as

the prices of fish and shellfish are higher than in peace time, and they have also taken up allotments where they cultivate vegetables for the market. The reduction in the number of fishermen soon decreased the quantity of periwinkles collected, and the mean annual amount sent away for the three years 1915-1917 was only twenty-eight tons. A bag of periwinkles contains 136 pints and weighs 1 cwt. 1 qr. There are about 125 periwinkles in a pint and an average bag will therefore contain 17,000. In twelve years, 1906-1917, over 500 tons of periwinkles were sent away by rail from Piel Station. The money value to the fishermen was at least £2,680.

The following table gives the monthly quantity in cwts. sent away from Piel Station on the Furness Railway since the beginning of 1906 :—

| | 1906 | 1907 | 1908 | 1909 | 1910 | 1911 | 1912 | 1913 | 1914 | 1915 | 1916 | 1917 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Jan. | 39 | 110 | 92 | 93 | 86 | 117 | 64 | 11 | 132 | 34 | 48 | 20 |
| Feb. ... | 72 | 102 | 90 | 125 | 108 | 103 | 79 | 38 | 109 | 38 | 53 | 61 |
| Mar. ... | 69 | 104 | 99 | 150 | 183 | 94 | 80 | 130 | 132 | 37 | 50 | 50 |
| April ... | 120 | 62 | 107 | 150 | 122 | 99 | 138 | 119 | 210 | 61 | 63 | 59 |
| May ... | 96 | 59 | 78 | 166 | 111 | 87 | 119 | 104 | 122 | 64 | 72 | 74 |
| June ... | 83 | 65 | 75 | 91 | 58 | 84 | 84 | 53 | 63 | 40 | 82 | 65 |
| July ... | 45 | 60 | 65 | 61 | 48 | 55 | 55 | 35 | 46 | 55 | 84 | 55 |
| Aug. ... | 60 | 45 | 57 | 36 | 63 | 59 | 48 | 20 | 51 | 50 | 68 | 42 |
| Sept. ... | 75 | 51 | 40 | 30 | 60 | 47 | 76 | 93 | 40 | 67 | 56 | 37 |
| Oct. ... | 112 | 58 | 63 | 42 | 98 | 93 | 46 | 86 | 45 | 60 | 28 | 40 |
| Nov. ... | 138 | 55 | 56 | 74 | 116 | 49 | 17 | 76 | 65 | 30 | 8 | 18 |
| Dec. ... | 95 | 63 | 89 | 65 | 77 | 49 | 13 | 98 | 36 | 16 | 12 | 3 |
| Totals ... | 1,004 | 834 | 911 | 1,083 | 1,130 | 936 | 819 | 863 | 1,051 | 552 | 624 | 524 |

At first sight the figures above might be thought to lead to the conclusion that the periwinkle industry of Barrow Channel is suffering a serious decline. If the prevailing conditions now and the present day results be taken into account and compared with the pre-war figures, it will be seen that there is really a marked increase in the output per man. The mean annual man average during the nine years 1906-1914 was slightly under six tons. The results of the year

1914 are included in this period as the most important season of the fishery was over before the reduced man-power could have noticeable effect. The three men who have carried on the industry since the beginning of 1915 to the end of 1917 have raised the mean annual man average to almost nine and a half tons. They also took an active part in the valuable stake-net plaice fishery at Roosebeck in the autumn 1916. This fishery reached its maximum in October, and came to an end through bad weather which also affected the collection of periwinkles in the last quarter of the year. One of the three men found temporary employment in November and December, 1917, repairing the breakwater connecting Foulney Island with the railway embankment. The other two at the same time engaged in line fishing for small cod, which were more remunerative than the periwinkles. The quantity of periwinkles sent away from Piel Station in December, 1917, was only three cwts. This is the smallest amount in the whole twelve years. This marked reduction is not due to a decline in the number of periwinkles present in the area. It is simply because they were not fished. It is probable that the same thing is taking place in the other minor inshore fisheries along our coast. The annual statistics in some cases may show a reduction when compared with pre-war results, but one must be certain that the man-power has not suffered depletion before we can say that there is a real decline. If the results could be analysed we would very likely find that the fishermen remaining at work are getting more fish and shell-fish per man than they did in the past. In the cases where the bare figures show a decline there may really be an increase per man, as in the Barrow Channel periwinkle industry.

Much will depend upon trade conditions after the war is over whether the men will return to their outdoor life and take up the periwinkle fishery again. The work may appear hard and monotonous to the ordinary observer, but the expert fisherman does not consider it so. It is probably not much harder

than cockle gathering, and the price per bag even in peace days was higher than was obtained for cockles. The expert periwinkle collector can easily obtain half a bag per tide. Many of them collected three-fourths of a bag before the returning tide drove them home. The periwinkle fisherman was able to live very comfortably in pre-war times on the income from his periwinkles, fish, fishing parties and market garden. He was probably better off on the whole than many of the workers in large factories where well defined hours are the custom, at any rate he was perfectly satisfied and had no desire to change his occupation till war restrictions compelled him.

# THE DIETETIC VALUE OF THE HERRING.

## (With Special Reference to the Manx Summer Fishery.)

By Jas. Johnstone, D.Sc.

Contents.



### Introduction.

This investigation was begun in the summer of 1914 and had reference then to the hydrographic researches which were in progress. We know, *in a general kind of way*, that all marine cold-blooded animals exhibit very clearly-marked metabolic cycles, sexual and nutritive, and that the phases of these cycles are to be associated with the seasonal changes in (at least) the temperature, the salinity and the alkalinity of the sea-water which is their environment. Various indices of the metabolic changes have been studied. The development of the genital organs, the percentage of oil in the liver and other tissues, the growth-rates, the " condition " of the animal as indicated by its weight per unit of length, and so on. It was known that there were marked variations in the percentage of oil contained in the flesh of Norwegian Brisling and that the variation of this constituent ran parallel with the annual variation in sea temperature. Summer-caught Brisling made good Norwegian

sardines because they were very fat while the winter-caught fish had a lower commercial value.* Of course the variation was also studied in a strictly scientific manner.

A similar variation was expected in the case of these Manx herrings. It was expected that the percentage of oil in the flesh would be small at the beginning of the fishery (in May), would rise with the increase of sea temperature and attain a maximum in August, and then would fall rapidly as the sea temperature decreased, and as spawning occurred. Such a metabolic cycle was found to exist, but the change in fat-contents was very much greater than previous work had led us to expect.

In the course of the investigation the dietetic aspect became a very obvious one to take up, and so the analyses, which at first dealt only with fat-contents, came to include the other "proximate food stuffs."

The investigation was extended to include herrings from other sources than the Manx fishery, cured fish, and sprats. It is not pretended that this research is complete, yet a greater amount of information is now available than has so far been in the possession of food investigators. It will be seen from the data given here that simply nothing is conveyed by any statement of the food value of "the herring"; the kind of fish must be specified before we can say what it is worth from the point of view of nutrition.

Finally there are the physiological problems—by far the more interesting ones. The seasonal changes that occur in the body of a fish were worked out by Miescher Reusch, in the case of the Rhine Salmon, and by Noël Paton and his colleagues in the case of Salmon from the Scottish coasts. It cannot be said that so much has been done, with regard to the salmon,

* All the British sprat-fisheries are winter ones and the fish, being relatively poor in fat, are inferior to the Norwegian brisling. Where are the British sprats in summer? At present there are no fisheries, and if there were the industrial (and food) resources of this country would be considerably increased.

that further investigation is unnecessary, and there is hardly anything of the same kind* in the literature with regard to the herring. Yet the seasonal changes that occur in the tissues of the latter fish are far more interesting and the economic value of investigation is vastly more evident.

This purely physiological research has not, of course, been attempted here. Obviously it would have been foolish to attempt it without considering also the food of the herring. Very interesting questions are suggested here: for instance, the origin of the oil that is so characteristic of marine Copepods and Schizopods from *their* food (Peridinians and Diatoms); the chemical nature of this oil and its relation with the oil of the herring; and the fate of the peculiar lipochromes that are present in the oil of the micro-crustacea.

Under present conditions the investigation of the latter questions is impossible, for plankton catches containing Diatoms, Peridinians, Copepods, &c., cannot be obtained in quantities large enough for analysis. And the amount of routine work that would be involved in an adequate study of the seasonal metabolism of the herring is so great that it could only be attempted by collaborators.

Therefore this report is to be regarded only as a general survey of the dietetic question—the food value of the English West Coast Herring.

## Methods.

These very technical details are necessary for criticism of the results set forth.

S a m p l i n g .

Fortnightly samples were received from Mr. T. N. Cregeen, of the Port Erin Biological Station, Isle of Man, during the months May to September of the years 1914, 1916 and 1917.

* With the exception of Milroy's study of seasonal changes. Rept. Fishy. Bd. for Scotland, Pt. III, 24th Ann. Rept. and Pt. III, 25th Ann. Rept.

Samples were received at irregular intervals from Fishery Officers in the Welsh part of the Lancashire and Western Sea Fisheries District. Some samples were received from Morecambe and others were bought in Liverpool shops. Cured herrings were also studied ; some salted fish obtained by Prof. Herdman, at Port St. Mary, and some salt herrings, bloaters, kippers and red herrings were purchased in shops.

The samples from Isle of Man consisted of 2 dozen fish each. They were very carefully packed and forwarded, and were almost always in fine (eatable) condition. As a rule they were dusted over with coarse dry salt.* Some of the samples (received in August) were cold-stored. It is difficult to say whether or not this had any effect on the composition.

The actual samples for analysis were always composite ones, that is, the material was derived from (usually) ten fish, 5 male and 5 female. Sampling the herrings was a matter demanding care. In most of the summer catches the quantity of *liquid* fat, or oil, contained in the flesh is so great that any process of mincing or chopping carried out in order to obtain a representative sample is impossible. Each herring tested was lightly washed and the scales on one side were rubbed away. The skin was then dried by rubbing lightly with a towel, and a series of transverse cuts, down to the backbone, were made with a sharp razor ; the cuts were about 1 millimetre apart. These slices were then freed by a tangential cut, right along the fish, made with a thin bladed knife so as to leave all the sections *in situ*. Slices from various parts, from each herring, were then taken up one by one with forceps and placed in a weighed extraction thimble contained in a weighing bottle. A little plug of cotton wool (to close the mouth of the thimble) was also contained in the bottle. The wet weight of flesh was found by difference. As a rule from 3 to 6 grammes of flesh formed each of these samples.

* This affected the composition *slightly* as will be seen later.

So rich in oil were some of the herrings that it was necessary to rinse out the weighing bottle. Oil actually oozed through the paper thimble.

In some cases larger samples of the flesh were taken—several dozen grammes. These were dried in the steam oven, extracted in a Soxhlet apparatus, ground to powder, dried again and stored.

Only the "flesh" of the herrings, including the skin (*minus* scales), was sampled. Since only relative results were required for the hydrographic research this was sufficient, and from the the point of view of dietetics it is only the flesh that matters. Adequate physiological investigation would, of course, have necessitated sampling other organs.

Drying.

This was really the most troublesome of all the operations involved in the analyses.

The flesh had to be dried in some receptacle that would absorb and retain the liquid oil oozing away at a high temperature. Therefore the samples were dried in the thick-walled paper thimbles* used for the oil-extraction. They were kept in a steam oven for about 24 hours after which the weight became constant. It is doubtful whether this process really "dries" the flesh but whatever the error may be cannot matter greatly, at any rate it had to be employed since vacuum-embedding apparatus or ovens running at high, constant temperatures were unavailable. Another source of error, suggested by Atwater † was also considered—the possible oxidation of the oil at high temperatures. This might have involved (1) raising the weight by oxidation, and (2) lowering the weight of oil extractable by rendering it insoluble. So a preliminary series of experiments were made.

* Those recently made by the Whatman people are very suitable, and admirable in every way.

† U.S.A. Department of Agriculture, 1906.

A paper thimble was perforated by a hole made by a cork borer and a little loose plug of cotton wool was placed at the bottom. The flesh was put in the thimble, with another loose cotton-wool plug on top. The thimble was closed by a perforated rubber cork and placed in a wide glass tube contained in a brine solution boiling at about 103° C. Air or hydrogen or carbon dioxide, previously dried and heated by passing through a coil of lead piping contained in the boiling pan, was then drawn or forced through the paper thimble.

The results (to which I refer later on) were not always consistent and must be repeated before any conclusions can be made. But it was evident (1) that there *was* some oxidation of the oil, (2) that the latter was not rendered insoluble, and (3) that increase in the weight of oil need not be taken into consideration, at all events not in results intended for dietetic studies.

More important was the great saving of time. By employing $CO_2$ (because of its higher specific heat) constant weight may be obtained in 4 hours, and an apparatus which would be very convenient and could deal with a number of samples could easily be fitted up.

However, all results quoted here were obtained by drying (at 97°-98° actually) in a steam-oven for about 24 hours at least.

Extraction of the oil.

This was carried out in an ordinary Soxhlet apparatus, using carbon tetrachloride as solvent. The process was always very simple and easy. Rarely, even in very dark oils, was there any trace of colour in the solvent after the third siphoning. As a rule the extraction was continued for 4 hours but, evidently, long before that time had elapsed the process had been finished. At first the last lot of solvent distilling over was tested by evaporation on a piece of white paper, but later on a definite routine was followed.

Whether or not appreciable quantities of substances other

than fats are thus extracted was not investigated. Lecithin, for instance, may be thus dissolved out from the flesh, but it is not certain that the quantity extracted is significant—in a dietetic investigation. Nor was the difference, if any, in solvent power, of ether and carbon tetrachloride studied—probably it does not matter. Strictly speaking we ought to speak of "extract" rather than of "oil" or "fat," but the latter terms may be used.

The dried flesh of the herring is *very* friable and easily crumbles to an impalpable powder. It was so friable that it was unnecessary to powder the dried substance before extraction (though this was done in some cases). Far different is the dried flesh of some other fishes, the plaice, for instance.

The water-free, fat-free residue.

After extraction the plugged thimble was replaced in its own weighing bottle and dried in the steam oven. The weight of the residue was found by difference and the total, water + oil + residue (three weighings), was used as a check. As a very general rule it did not differ by more than 0·5% from 100. Very often the error was in excess, and was regarded as the gain in weight due to oxidation of the oil (though this is a matter requiring further study). If there were wider deviations the analyses were repeated.

As a rule two samples were taken. The contents of the thimbles were taken out, powdered in an agate mortar, re-dried and stored. Usually there was enough to enable both proteid and ash estimations to be made. If not, the reserve of dried material (when this had been prepared) was used for these purposes.

The proteid estimations.

Proteid was estimated by the Kjeldahl process. None of the 1914 samples were examined in this way, but all the 1916 dry, fat-free residues were kept with the object of estimating

proteid. The amount of residue in the single samples was rather small, so those for each month were mixed together and the composite samples so formed were estimated (as shown in Tables II-III). In all cases 0·500 gram of the dried residue was taken and digested in 20 c.c. of pure sulphuric acid, using potassium sulphate and a small globule of metallic mercury. A first complete series of estimations of the 1916 and 1917 samples was made using copper sulphate instead of mercury, but since several of these estimations appeared to be erroneous the whole series of analyses was repeated, varying the process in detail, using mercury instead of copper sulphate, and employing different reagents and standard solutions—with two or three exceptions the results were nearly the same, but the latter series of estimations is that quoted.

The process was perfectly straightforward. There was very little frothing of the mixture of residue and acid, and the reduction to a colourless solution took about two hours, as a rule. Some difficulty was, however, experienced in the cases of the residues from the flask of salted herrings and the reduction took the greater part of a working day. In two cases there was no precipitate of mercury sulphide on adding sodium sulphide solution to the diluted acid, and the cause was apparent, the residues contained from 20 to 40% of salt and a chloride of mercury was produced which volatilised during the reduction. Afterwards the residue was digested with sulphuric acid and potassium sulphate for about half an hour and then the mercury was added. In these cases the whole process then went normally.

It was found advantageous to boil the diluted acid solution, after adding the sodium sulphide, so as to get rid of $H_2S$. This seemed to improve the end-point of the titration.

Litmus was used for an indicator, and decinormal solutions of sulphuric acid and sodium hydrate were employed in the titration.

The propriety of using the factor 6·25 to convert the nitrogen found into proteid is discussed later on.

Non-volatile mineral matter.

When there was sufficient of the dried residue, some of this was incinerated in porcelain capsules. After about ½ hour of ignition at a low red heat a drop or two of nitric acid was added to the cooled residue so as to obtain a white ash. The capsule was then again ignited to a full red heat.

This weighing gave the " ash " of the Tables. It is not suggested that it precisely represents the mineral matters present in the raw flesh, but it is probably a near approximation.

As will be seen from the Tables many of the individual samples were examined in full detail.

## The Analytical Results.

### I. *Manx Summer Herrings*, 1914.

| Date. | Sex. | Condition. | % of Water. | % of Oil. | % of Oil and Water. |
|---|---|---|---|---|---|
| 3 June | ♂ | Virgin | ... | 5·3 | ... |
| ,, | ♀ | ,, | ... | 3·6 | ... |
| 25 June | ♂ | Filling | ... | 27·8 | ... |
| ,, | ♀ | ,, | ... | 26·8 | ... |
| 2 July | ♂ | ,, | 57·5 | 24·4 | 81·9 |
| ,, | ♀ | ,, | ... | 29·5 | ... |
| 9 July | ♂ | ,, | 48·4 | 32·5 | 80·9 |
| ,, | ♀ | ,, | 46·6 | 34·9 | 81·5 |
| 31 July | ♂ | Full | 61·2 | 16·9 | 78·1 |
| ,, | ♀ | ,, | 44·7 | 26·5 | 71·2 |
| 22 Aug. | ♂ | ,, | 53·5 | 23·7 | 77·2 |
| ,, | ♀ | ,, | 62·3 | 17·6 | 79·9 |
| 4 Sept. | ♂ | Spawning | 63·4 | 16·3 | 79·7 |
| ,, | ♀ | ,, | 60·2 | 18·1 | 78·3 |
| 30 Sept. | ♂ | Spent | 63·9 | 9·0 | 72·9 |
| ,, | ♀ | ,, | 66·3 | 8·9 | 74·2 |

## II. *Manx Summer Herrings*, 1916.

| Date. | Sex and Condition. | % of Water. | % of Oil. | % of Proteid. | % of Ash. |
|---|---|---|---|---|---|
| 25 May ... | ♂ Virgin .............. | 75·4 | 2·5 | 21·1 | ... |
| ,, ... | ♀ ,, .............. | 74·7 | 2·6 | | |
| 9 June ... | ♂ ,, .............. | 73·5 | 4·5 | | |
| ,, ... | ♀ ,, .............. | 72·9 | 4·6 | 18·6 | 2·03 |
| 22 June ... | ♂ Filling ........... | 58·4 | 18·8 | | |
| ,, ... | ♀ ,, ........... | 59·6 | 17·5 | | |
| 5 July ... | ♂ ,, ........... | 58·4 | 17·6 | | |
| ,, ... | ♀ ,, ........... | 60·9 | 14·0 | 18·4 | ... |
| 21 July ... | ♂ ,, ........... | 52·3 | 26·1 | | |
| ,, ... | ♀ ,, ........... | 51·6 | 28·7 | | |
| 3 Aug. ... | ♂ Half-full ........... | 47·1 | 32·9 | ... | ... |
| ,, ... | ♀ ,, ........... | 49·1 | 30·0 | ... | ... |
| 17 Aug. ... | ♂ ,, ........... | 48·6 | 31·5 | 16·5 | ... |
| ,, ... | ♀ ,, ........... | 48·7 | 31·8 | | |
| 1 Sept. ... | ♂ Full .............. | 48·6 | 27·8 | 15·3 | ... |
| ,, ... | ♀ ,, .............. | 45·1 | 38·3 | | |
| 14 Sept. ... | ♂ ,, .............. | 51·8 | 22·1 | | |
| ,, ... | ♀ ,, .............. | 53·1 | 22·2 | 19·3 | 2·63 |
| 30 Sept. ... | ♂ ,, .............. | 56·3 | 19·3 | | |
| ,, ... | ♀ ,, .............. | 56·2 | 21·2 | | |

## III. *Manx Summer Herrings*, 1917.

| Date. | Condition, &c. | % of Water. | % of Oil. | % of Proteid. | % of Ash. |
|---|---|---|---|---|---|
| 11 May ... | Pectoral, virgin ...... | 70·6 | 3·5 | 19·9 | 3·34 |
| ,, ... | Trunk ,, ...... | 71·1 | 2·9 | | |
| 21 May ... | Pectoral ,, ...... | 65·5 | 7·8 | 19·5 | ... |
| ,, ... | Trunk ,, ...... | 67·0 | 7·5 | | |
| 6 June ... | All regions, filling ... | 58·0 | 13·2 | 22·8 | ... |
| 21 June ... | Pectoral ,, ... | 43·5 | 33·2 | 17·7 | 3·36 |
| ,, ... | Trunk ,, ... | 45·4 | 32·6 | | |
| 4 July ... | Pectoral ,, ... | 45·2 | 31·8 | 17·1 | ... |
| ,, ... | Trunk ,, ... | 47·9 | 30·2 | | |
| 19 July ... | Pectoral, $\frac{1}{2}$-full ...... | 38·3 | 41·8 | 15·3 | 2·55 |
| ,, ... | Trunk ,, ...... | 43·9 | 35·9 | | |
| 31 July ... | All regions, $\frac{3}{4}$-full ... | 42·7 | 37·7 | 15·8 | 2·55 |
| ,, | ,, Port Erin Bay | 36·0 | 39·3 | 20·2 | ... |
| 15 Aug. ... | ,, full ...... | 43·5 | 36·6 | 15·7 | 2·85 |
| 11 Sept. ... | ,, ,, ...... | 44·1 | 33·9 | 17·6 | 1·65 |

## IV. *Winter Herrings.*

| Date. | Condition, &c. | % of Water. | % of Oil. | % of Proteid. | % of Ash. | Total. |
|---|---|---|---|---|---|---|
| 1913. | (*a*) *Coast of Wales.* | | | | | |
| 10 Dec. ... | ♂ Spent ............... | ... | 4·1 | ... | ... | ... |
| ,, ... | ♂ Full ............... | ... | 8·8 | ... | ... | ... |
| ,, ... | ♂ Spent ............... | ... | 1·2 | ... | ... | ... |
| 19 Dec. ... | ♂ ♀ Spent ......... | ... | 2·8 | ... | ... | ... |
| ,, ... | ♂ ♀ Spent ......... | ... | 8·7 | ... | ... | ... |
| 1914. | | | | | | |
| 27 Oct. ... | ♂ Full ............... | 63·8 | 18·6 | ... | ... | ... |
| ,, ... | ♀ ,, ............... | 69·1 | 11·3 | ... | ... | ... |
| 19 Nov. ... | ♂ ,, ............... | 60·4 | 22·5 | ... | ... | ... |
| ,, ... | ♀ ,, ............... | 68·9 | 11·8 | ... | ... | ... |
| 20 Nov. ... | ♂ ,, ............... | 63·4 | 19·1 | ... | ... | ... |
| ,, ... | ♀ ,, ............... | 65·0 | 16·5 | ... | ... | ... |
| 9 Dec. ... | ♂ ,, ............... | 63·8 | 18·6 | ... | ... | ... |
| ,, ... | ♀ ,, ............... | 69·9 | 11·7 | ... | ... | ... |
| 18 Dec. ... | ♂ Virgin ............... | 68·9 | 10·3 | ... | ... | ... |
| ,, ... | ♀ ,, ............... | 71·3 | 7·7 | ... | ... | ... |
| 1917. | | | | | | |
| 30 Nov. ... | 3 Full ♂, 3 Virgin ♀ | 61·1 | 22·38 | 15·53 | 0·97 | 99·96 |
| 29 Nov. ... | ♂ ♀ Full ........... | 60·3 | 22·87 | 15·46 | 1·03 | 99·68 |
| | (*b*) *Shop herrings.* | | | | | |
| 18 Oct. ... | ♂ Full ............... | 49·91 | 35·6 | ... | ... | ... |
| 20 Nov. ... | ♂ ,, ............... | 53·94 | 32·77 | 12·66 | 1·26 | 100·63 |
| 29 Nov. ... | ♂ ♀ ,, ............... | 65·53 | 17·53 | 15·48 | 0·87 | 99·41 |
| 1918. | | | | | | |
| 8 Feb. ... | ♂ Large, full ........ | 69·95 | 13·74 | 15·57 | 1·29 | 100·63 |

## V. *Cured Herrings.*

| Date. | Origin, Condition, &c. | % of Water. | % of Oil. | % of Proteid. | % of Ash. | Total. |
|---|---|---|---|---|---|---|
| 1917. | | | | | | |
| 1 May ... | SALT, Shop, spent ... | 50·61 | 12·01 | 24·48 | 9·73 | 96·83 |
| 7 June ... | SALT, ,, full ... | 47·80 | 20·61 | 22·93 | 6·33 | 97·67 |
| 13 Dec. ... | SALT, Manx, ,, ... | 38·29 | 32·72 | 15·47 | 12·53 | 99·01 |
| 16 Nov. ... | KIPPER, Shop, good | 59·97 | 13·98 | 21·71 | 3·50 | 99·16 |
| 1918. | | | | | | |
| 30 Jan. ... | BLOATER, ,, ,, | 50·22 | 18·29 | 19·22 | 9·65 | 97·38 |
| 3 Feb. ... | RED, ,, ,, | 45·84 | 17·51 | 26·49 | 12·63 | 102·47* |

* See p. 127.

VI. *Immature Herrings* (*Morecambe*).

| Date. | Length. | % of Water. | % of Oil. | % of Proteid. | % of Ash. | Total. |
|---|---|---|---|---|---|---|
| 1914. | | | | | | |
| 24 May ... | About 12 cms. ...... | ... | 3·0 | ... | ... | ... |
| 30 „ ... | „ ...... | ... | 4·1 | ... | ... | ... |
| 30 „ ... | „ ...... | ... | 3·2 | ... | ... | ... |

VII. *Sprats* (*Morecambe*).

| Date. | Condition. | % of Water. | % of Oil. | % of Proteid. | % of Ash. | Total. |
|---|---|---|---|---|---|---|
| 1914. | | | | | | |
| 29 May ... | Immature, small ... | ... | 9·5 | ... | ... | ... |
| 1915. | | | | | | |
| 27 Jan. ... | Large, mature ...... | 70·0 | 11·9 | ... | ... | ... |
| 1918. | | | | | | |
| 29 Jan. ... | Large, mature ...... | 67·95 | 13·21 | 17·74 | 1·28 | 100·18 |

## Composition of the Flesh of Fresh Herrings, Cured Herrings and Sprats.

General Remarks on the Analytical Results.

It is necessary to make some remarks with regard to the general question of the accuracy of the analyses.

First of all we must note that the totals for water, oil, proteid and ash in the Manx Summer Herrings of 1916 and 1917 show a deficiency. The mean results for all the samples received during each month are given in the Table on p. 103. Excluding the analyses of May, 1916, we see that the mean totals for water, oil, proteid and ash are 97·8% for 1916 and 97·9% for 1917. Thus there is a deficiency of 2%, and this is greater than the experimental errors.

The cause for this deficiency was investigated in a preliminary way. First of all it was suggested that the fat ex-

traction was incomplete and that there was still some oil in the dried residues. That would have depressed the proteid value, which is calculated on the wet weights. But renewed extraction of the residues, reduced to fine powders, gave no appreciable amount of oil, and had there been such it would have become apparent by forming a soap in the process of distillation, during the Kjeldahl estimations. If the fat is erroneously estimated it ought to be an error in excess due to a possible extraction of some substance such as lecithin, or to incomplete drying of the oil (the carbon tetrachloride being adsorbed to a slight extent), or to oxidation of the oil during the drying in air.

It is certain that such oxidation occurs. The oil extracted is *always* dark brown in colour, but if the drying of the wet flesh is carried out as suggested above, in an atmosphere of hydrogen or carbon dioxide, and if the subsequent drying of the oil is also carried out, in a similar indifferent atmosphere, then the oil obtained is light yellow in colour, with a crystalline substance separating out on cooling. That fish oils oxidise in air at high temperatures is well known, and the principal means of obtaining a colourless, medicinal cod-liver oil that does not produce eructation when administered, is the exclusion of air during the process of preparation of the oil. An indifferent atmosphere of $CO_2$ is, in fact, used. Further there are significant variations in the refractive indices of the herring oils obtained in various ways. Thus we have :—

| | | |
|---|---|---|
| Extracted and dried in air ... | Refractive index | = 1·388. |
| Extracted and dried in $CO_2$... | ,, ,, | = 1·378. |
| Kipper oil, air-dried ... ... | ,, ,, | = 1·381. |
| Red herring oil, air dried ... | ,, ,, | = 1·455. |

The previous oxidation of the kipper and red herring oils raise the index of refraction.

But the effect, with regard to weight, is very small, as will be seen by drying a sample persistently in the air oven and observing the rise in weight. It is, probably, a lipochrome,

or some other substance present in very small quantity, that is oxidised.

It was also suggested that the deficiency was due to the imperfect drying of the wet substance, but reflection upon this possible source of error does not support the suggestion.

Finally there are possible errors in the estimation of nitrogen by the Kjeldahl process. Now it is perhaps unnecessary to state that blank and control experiments were made. A piece of N-free Swedish filter paper was substituted for the proteid-containing residue, and the operations were then carried out in all respects as if an actual estimation were being made. Then distillations and titrations were made, using pure ammonium chloride instead of the diluted acid from the Kjeldahl flask. In both cases small departures from zero or the theoretical percentage were obtained, but these sources of error were so small that it was not regarded as necessary to correct the results stated in the Tables.

However, we see from Table IV, that the Winter herrings show more satisfactory totals. The mean of 5 analyses is :—

61·8 % water, 21·9 % oil, 14·9 % proteid, 1·1 % ash = 99·7 %,

and it is therefore evident that we have to deal with a real deficiency, that is, there is, in the flesh of the Manx Summer herrings some substance not found by the usual processes of estimating fat or proteids.

We discuss later what this substance may be.

Differences between Summer and Winter herrings will also be noticed with respect to the percentage of ash recovered from the residues. The Manx Summer herrings of 1916 and 1917 gave 2·33 and 2·75 per cent. respectively, while the Winter-caught shop and Welsh herrings gave 1·08. But this difference is easily to be accounted for by the fact that the Manx fish were slightly salted. Thus some sodium chloride was added to the tissues, and some water withdrawn. The difference in ash in the two kinds of fish is about 1·5%.

## The Food Value of Manx Herrings.

First of all we have to consider the "waste," that is, the proportional weight of the fish that is not eaten. A certain number of experiments were made to find this waste value. The herrings (usually 3 or 5 fishes) were beheaded, and the viscera (except roes and milts) were removed; the fins were cut away; the backbone and as many as possible of the small bones were removed and the skin was also removed. In the salt ones we may eat the skin and the small bones which, when fried, are quite brittle and so leave nothing but head and backbone. Only those parts of the herring usually capable of being eaten were regarded as "edible." The results are as follows:—

*Ratio of Edible to Inedible Parts.*

| Date and Origin. | Edible % | Inedible % |
|---|---|---|
| May 11, Manx, ♂ ♀, virgin ... ... ... | 57 | 43 |
| June 21, ,, ,, ... ... ... | 63 | 37 |
| July 4, ,, filling ... ... ... | 59 | 41 |
| July 19, ,, ,, ... ... ... | 68 | 32 |
| Sept. 11, ,, full ... ... ... | 72 | 28 |
| May 1, shop, ♂ ♀, virgin ... ... ... | 68 | 32 |
| Feb. 8, ,, ♂ full ... ... ... | 63 | 37 |
| May 1, Salt, ♂, spent ... ... ... | 62 | 38 |
| May 5, Salt, ♀, full ... ... ... ... | 73 | 27 |
| June 7, Salt, ♂ ♀, full ... ... ... | 72 | 28 |
| Dec. 13, Salt, Manx, ♂ ♀, full ... ... | 76 | 24 |
| Nov. 16, Kipper ... ... ... ... | 66 | 34 |

Thus the percentage of inedible parts or "waste" in fresh herrings varies between 28 and 43, while in salted herrings it varies between 24 and 38. These limits are not very wide, and it will be a safe working rule to place the proportion of inedible substance in good, full, Summer-caught herrings as about one-third.

The variation depends upon two factors, (1) the growth of the reproductive organs (roes and milts) which are really edible,

though they may not always be eaten. The reproductive organs are very large in full herrings and may attain a weight of about 1/7th of the total body weight. As the season advances this proportional weight of ovaries and testes rises, as is shown in the following Table, where Hjort's scale of stages of development is adopted.

Stages I to II are virgin fish with very small ovaries and testes ;

Stages III to V are fish with large ovaries and testes, not quite " full " herrings, but approaching this condition;

Stages VI to VII are " full " fish which may even be actually spawning.

" Spent " fish are here included in Stage I.

*Manx Summer Herrings, Stages of Development.*

| | I–II. | III–IV–V. | VI–VII. |
|---|---|---|---|
| May ... ... ... ... | 72 | ... | ... |
| June ... ... ... ... | 88 | 7 | ... |
| July ... ... ... ... | 49 | 72 | ... |
| August ... ... ... | 5 | 46 | 20 |
| Sept. ... ... ... ... | 3 | 19 | 94 |

Altogether 475 Manx fish were examined individually during the two seasons of 1916-17. It will be seen from the above results (which can be made more detailed, if necessary, by reference to Riddell's report on the 1913 fishery)* that the size of the roes and milts gradually increases as the season goes on. With this increase in the bulk of the gonads, the nutritive value of the herrings increases. Towards the end of the season the fish spawn, the roes and milts shrink up and decrease to a very small fraction of the total body weight, and the nutritive value falls off very greatly.

But accompanying this increase in the mass of the reproductive organs there is also an increase in the weight of the fish

* *Ann. Rept. Lancashire Sea-Fish. Laby. for* 1914, pp. 109-138. 1915.

in proportion to its length: the herrings "put on flesh." In the case of an average-sized fish, of (say) 23·5 cms. (that is $9\frac{1}{4}$ inches) the average weight will be about 73 grms. (that is about $2\frac{1}{2}$ozs.) at the beginning of the season. But by the end of the season, herrings of the same length will weigh about 121 grms. (that is about 4 ozs.). This increase in weight is due partly to the growth of the ovaries and testes and partly to the increase in tissue.

It may be useful to state these latter results in greater detail.

When the samples were received, the fish were sorted out into centimetre groups, thus all those over 20 and less than 21 cms. long were placed in a group with mean length of 20·5 cms. and so on. All the fish in each group were then weighed and mean weights were calculated. Thus we get series, as, for instance:—

9 June, 1916, 24 herrings.

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Mean length = | 22·5 | 23·5 | 24·5 | 25·5 | 26·5 | 27·5 | 28·5 | cms.; |
| Mean weight = | 79 | 92 | 95 | 104 | 114 | 124 | 161 | grams. |

A freehand curve could then be drawn, plotting mean length against mean weight.

But it is more accurate to calculate a probability curve, thus avoiding bias in drawing a graph for such rather irregular data. It can easily be shown that the curve that represents, with greatest probability, the increase of weight with increasing length is:—

$$\textit{Mean weight} = \textit{a constant} + al + bl^2 + cl^3, \text{\&c.}$$

Where $a$, $b$ and $c$ are coefficients and $l$ is the mean length. For such small samples as these we may take the modified function.

$$\textit{Mean weight} = al^3.$$

Further it is easy to show that the coefficient $a$ is given by

$$\frac{4\,(\text{weight of all the fish in the sample})}{l_2^4 - l_1^4}$$

Where $l_2$ is the highest mean length $+$ 0·5 cm. and $l_1$ is the lowest mean length $-$ 0·5 cm.

Working out all these series (really a very simple matter) we get values of the coefficient $a$, thus enabling us to draw smooth probable growth-curves. The coefficient $a$ is really a measure of the nutritive condition of the fish and describes the whole sample. Finding mean $a$'s for the two years 1916-17 we get :—

| | | | |
|---|---|---|---|
| May | $a = 0{\cdot}00585$ ; | weight of herring $=$ 23·5cms.$=$ | 76 grms. |
| June | $a = 0{\cdot}00705$ ; | weight of herring $=$ 23·5cms.$=$ | 92 grms. |
| July | $a = 0{\cdot}00825$ ; | weight of herring $=$ 23·5cms.$=$ | 107 grms. |
| Augt. | $a = 0{\cdot}0092$ ; | weight of herring $=$ 23·5cms.$=$ | 119 grms. |
| Sept. | $a = 0{\cdot}0087$ ; | weight of herring $=$ 23·5cms.$=$ | 113 grms. |

These variations in the numerical value of $a$ make really quite considerable differences in the mean weights. The curves need not be given as they can very easily be reproduced from the equation $W = al^3$. We see, however, that $a$ increases from May to August, and then decreases because the "condition" of the fish is falling off during the latter month and some of them are beginning to spawn.

Thus there is a gradual increase in the food value of each herring during the progress of the season because the fish is becoming plumper and its roes or milts are enlarging. There is also a change in the chemical composition of the flesh such that the fish is, all the while, becoming a better article of food. This change consists of (1) an increase in the amount of oil contained in the flesh, and (2) a decrease in the amount of proteid. The former change has a far larger effect than the latter so that the net effect is to increase the food value of herrings. These changes are recorded in detail in Tables I-III, but they will be better seen by making summaries of Tables II and III. In the following tables the numbers are percentages of the net weight of fresh herring flesh.

*Manx Summer Herrings: Fisheries of* 1916 *and* 1917.
*Composition of the flesh of the fish. Monthly means.*

| Date. | Condition. | Water. | Oil. | Proteid. | Ash. | Total. | Energy Values. |
|---|---|---|---|---|---|---|---|
| 1916. | | | | | | | |
| May | ... Virgin ...... | 75·0 | 2·5 | 21·1 | 2·3 | 100·9 | 1,100 |
| June | ... Filling ...... | 66·1 | 11·4 | 18·6 | 2·0 | 98·1 | 1,806 |
| July | ... ,, | 55·8 | 21·6 | 18·4 | 2·3 | 98·1 | 2,762 |
| Aug. | ... ½-Full ...... | 48·4 | 31·5 | 16·5 | 2·3 | 98·7 | 3,608 |
| Sept. | ... Full ......... | 51·9 | 25·2 | 17·3 | 2·6 | 97·0 | 3,050 |
| 1917. | | | | | | | |
| May | ... Virgin ...... | 68·5 | 5·4 | 19·7 | 3·3 | 96·9 | 1,330 |
| June | ... Filling ...... | 49·0 | 26·3 | 20·3 | 3·7 | 99·3 | 3,279 |
| July | ... ,, ...... | 43·6 | 35·5 | 16·1 | 2·6 | 97·8 | 3,959 |
| Aug. | ... Full ......... | 43·5 | 36·6 | 15·7 | 2·9 | 98·7 | 3,943 |
| Sept. | ... ,, ......... | 44·1 | 34·0 | 17·5 | 1·7 | 97·3 | 3,876 |

This table shows the remarkable variation in the chemical composition of herring flesh. Proteid, it will be seen, varies from about 15½% to 21%, but even this is much less striking than the variability in the fat. This rises from about 2½% at the beginning of the season, to over 35% at about the time of maximum sea temperature, at which time the fish are becoming "full" and are not far from the spawning phase. In 1916 and 1917 the spawning time was relatively late in the year, September, and possibly October, and the fishery ceased on account of bad weather before samples of spent fish could be procured. In 1914, however, spawning occurred early in September, and spent fish were thus obtained, when it was found that the percentage of fat had been reduced to about 9%. No doubt it decreased still further as the sea temperature fell and the shoals dispersed after spawning.

We consider the purely physiological aspect of these changes later on (but only in a preliminary way). Meanwhile something must be expected to be said about the

Energy-value of herring-flesh.

"Energy-values" are really what chemists call "heats of combustion" stated in a certain way. "Heat of com-

bustion " is the quantity evolved when a substance, like cane sugar, is completely oxidised in a calorimeter, so that, in the case of herring flesh the heat of combustion, or energy-value, would be found by burning a weighed quantity of the dried substance and estimating the quantity of heat evolved. The latter is expressed in calories, a calorie being that amount of heat required to raise the temperature of one kilogramme of water through a range of 1 degree Centigrade, measured from a certain starting point.

In finding energy-values of foodstuffs it is assumed that the substances are as completely oxidised in the human body as they would be when burned in a calorimeter with all possible precautions of experiment.

In general the actual heats of combustion are not experimentally found. It is usually assumed that all " fats " are the same, and that all " proteids " are also the same, with respect each to its heat of combustion. In practice the percentages of " fat," that is, of ether-extract, and of " proteid," that is, of nitrogen multiplied by the factor 6·25, are found. " Fat " is multiplied by 9·3 and proteid by 4·1, and the products are added together. The sum is then multiplied by 10 so giving the heat of combustion, or " energy-value " of the foodstuff in calories per kilogramme.

It does not follow that the heat of combustion obtained experimentally, is necessarily the same as the energy-value estimated as indicated above. Usually the difference between experimental and calculated energy-values is not found. In the case of a published series* of analyses of cooked fish the following values were obtained experimentally :—

| | Heats of combustion found by experiment. | Energy Values found by calculation from the analyses. |
|---|---|---|
| Flesh of Salt Herring ... ... | 4,134 | 4,352 |
| Flesh of Fresh Herring ... ... | 4,655 | 5,098 |
| Flesh of Sprat ... ... ... ... | 5,019 | 5,326 |
| Flesh of Cod ... ... ... ... | 5,672 | 4,133 |

* Miss K. Williams, " The Composition of Cooked Fish," *Journ. Chem. Soc., Trans.*, Vol. LXXI, 1897, pp. 649-53.

These results apply, of course, to the dried flesh. The differences are notable, and whether or not they are of significance depends upon the use to be made of the results.

Thus the "energy-value" of fish-food stuff must not be taken at its "face value." Very little is known as to the chemical nature of the proteids and fats (or rather oils) in the common species of British fishes used as food, for in most cases the proteid-values are (experimentally) nitrogen-values, while the "fats" are always ether-extracts and are thus mixtures, which are probably rather different in different species and even in the same species of fish caught on the same fishing ground but at different seasons of the year. Further the energy-values ought (as we shall see later) to be deduced from analyses which give the composition of the fish at all seasons, and not at some particular time. It is, of course, well known that the "condition" (that is the nutritive value) of all species of fishes varies largely throughout the year. Thus the flesh of mature plaice and cod is more "watery" at the time shortly after spawning occurs than at any other seasonal phase. Plaice which have immature sexual organs are in very poor "condition" during February and March, the months of minimal sea-temperature. Thus two factors affect "condition," and so energy-value—the sexual phase and the sea temperature. Analyses must be made at all stages and periods if they are to be made use of to furnish energy-food tables. So far as I can find, such series of analyses have only been made for the Herring.*

The effects of cooking and methods of preservation and curing must also be considered.

## Effects of Cooking and Curing Methods.

So very little is known with regard to the effect of cooking and of methods of salting, drying, smoking, &c., that energy-values become still more doubtful when used in dietetic dis-

* By Milroy, *loc. cit.*, and by myself.

cussions and estimates. It is *very* remarkable that the analyses of fresh uncooked fish flesh should be made use of in this way without qualifications, involving, as such estimates do, the tacit assumption *that fish is eaten raw.* Thus the Royal Society Food (War) Committee* give a list of analytical results of raw fish flesh which are expanded into absolute quantities of proximate food-stuffs, which again are expanded in terms of energy-values.

It is most unfortunate that there are so few analyses of cooked fish. So far the only results I can find in the literature are those of Miss Williams (see footnote on a previous page), and these are of little value since there are no corresponding analyses of the same fish in the uncooked state.

Whether or not cooking produces actual chemical changes which alter the energy-values of the constituents of the flesh, has not been experimentally determined. But there can be little doubt that such changes occur. Certain grosser effects may, of course, occur. Thus fat-rich fresh herrings and kippers which are fried must lose a considerable proportion of their fat, and the latter is unfortunately unavailable (because of its odour) for other cooking processes. The prolonged soaking of salted herrings and of dried cod may also diminish the food value, perhaps to quite a considerable degree. It is known that both distilled water and (still more) salt solution will dissolve out nitrogenous extractives from fish flesh—gelatine and no doubt other coagulable proteids. Both salted herrings and dried cod are cured at low temperatures so that there may be no coagulation of proteid substances, and so no loss of solubility. In such process as that of kippering there may be some superficial coagulation of proteid which may protect the flesh against solution in subsequent cooking operations.

It is also probable that boiling fish may be so carried out

* The Food Supply of the United Kingdom: A White Paper, cd. 8421, 1917.

as to bring about a considerable loss of nitrogenous material, gelatine and watery extracts.

By far the greatest effect (from the point of view of the public food supply) is that produced in fresh herrings by the ordinary method of cooking—that is, frying. No doubt the very high energy-values for these Manx herrings are largely unavailable values, for large quantites of oil must be lost in the cooking process. It appears that there is only one way in which these large fat-contents may become actually available as food, that is, by cooking or preparing the fish in such a way as to " fix " the oil in the flesh. The well-known process of " potting " (Lancs.) fresh herrings by cooking in simmering vinegar does seem to fix the fat. There is little or no escape of oil into the liquid in the cooking vessel, and the flesh of the fish has a firm consistency and appearance which suggests actual solidification of the oil. The only tentative experiments which I have made (obviously the ordinary Laboratory is badly equipped for this work) seem to suggest that this retention, in an assimilable and easily digestible form, of the oil is actually obtained by the cooking in hot vinegar.

Of course, fat " mordants " are known in histological work. Acetic acid and potassium bichromate are used to fix fat droplets in tissues and prevent their solution in the processes of preparing sections. Of course such powerful reagents can hardly be employed in cooking operations, nor is it desirable that the oil should be rendered insoluble, but on the other hand, " marinaded " herrings and other Clupeoid fishes have long been known and in these processes of conservation there is probably fixation of fat. Then there are the sardining processes in which preliminary slight salting and drying are apparently essential steps, and there are of course the processes of conservation in various sauces and even in white wine.

The fact seems to be that a full utilisation of the Clupeoid fish supply of the United Kingdom seems to be possible only by employment of some conserving methods.

## Composition of Cured Herrings.

Some analyses of herrings cured commercially are given in the previous pages. Now all this work is very interesting, not only from the purely abstract side, but also from the aspect of national food resources. It is only just touched here. Obviously all the various trade and official categories of salted herrings must be studied, Winter and Summer " fulls " and " spents," " matties," &c., and the differences in composition are certain to be considerable. Thus, even in the three analyses made, water (in salted herring flesh) varies between about 38 and 51, oil between 12 and 33, proteid between 15 and 24, and salt between 6 and 13—all in percentages of the wet, raw flesh, of course. Obviously it is nearly as difficult to say what is a " salted or pickled herring " chemically as it is to describe similarly a fresh herring.

The mean of the three analyses, is, however :—

*Pickled Herrings, composition of flesh.*

| | |
|---|---|
| Water ... ... ... ... ... ... | 45·6 % |
| Oil ... ... ... ... ... ... | 21·8 % |
| Proteid ... ... ... ... ... ... | 20·9 % |
| Ash (including salt) ... ... ... ... | 9·5 % |
| | 97·8 % |

(The deficiency to which allusion has already been made is here apparent.)

### Chemical Effect of Salting Herrings.

What effects follow from the drastic salting of fresh herrings are not fully investigated. There is probably little loss of oil but some loss of nitrogenous substance which becomes the greater the longer the herrings are kept in pickle. The latter is said to contain trimethylamine (to which it owes its

smell), at any rate its nitrogenous constituents are chiefly amino-bases, with small quantities of coagulable proteids, globuline, albumose, xanthin bases. There are no nucleo-proteids, apparently, though phosphoric acid very slowly accumulates in the pickle. So does the quantity of potassium salts.*

Thus there is an appreciable loss of valuable food-stuffs in the course of the conservation of herrings by means of pickling in brine.

The immediate chemical and physical effects † of pickling in brine are (1) the withdrawal of water, (2) the addition of salt, and (3) the increase in proteid-substances. After a while the latter, of course, decrease. But far too little is known concerning these changes. I have only been able to make two analyses which have relevancy in this connection. The Manx Summer Herring Fishery of 1917 ended in September, and I am indebted to Prof. Herdman for two salted herrings which belonged to a barrel which he had cured at this time. The full analyses made gave the following figures (percentages of wet flesh):—

| | Water. | Oil. | Proteid. | Ash. | Total. |
|---|---|---|---|---|---|
| 11th Sept., 1917, fresh | 44·12 | 33·95 | 17·54 | 1·65 | 97·26 |
| Sept., 1917, salted | 38·29 | 32·72 | 15·47 | 12·53 | 99·01 |

But one must not assume that these herrings were originally the same in composition (that is, in the fresh state), since even a short time at the end of the season may lead to considerable diminution in oil contents and increase of water. It is evident from the analyses that the fresh herrings must have had a larger water percentage than had those which were salted. One sees that salt (the " ash " except about 1 to 1·5%) replaces

* See S. Schmidt-Nielsen. *Rept. on Norwegian Fishery and Marine Investigations*, 1900, 1, no. 8.

† *Ibid.*

water, and that some proteid is lost, since these Manx salted Summer herrings ought to have had more proteid than $15\frac{1}{2}\%$. The oil-contents, are, however, much the same.

Other Cured Herrings.

Some other analyses of cured herrings are given in Table V: Kippers, Bloaters and Reds. The analysis of the kippers was made (like that of the salted herrings) from a composite sample taken from two fishes, but that of the bloater and red were made from one fish (all parts of the flesh being sampled). Remembering the variability in composition of the fresh fish, one must not expect much from single analyses. It is clear, however, that bloaters approximate in composition to salted herrings (though they are probably better articles of food). Kippers are, of course, lightly salted and are relatively highly concentrated proteid foods, because the withdrawal of water is the effect of simple drying and not of the replacement by salt. The oil, too, must be retained to a great extent. The red herrings are evidently the most highly nitrogenous of all cured herrings though the high salt-percentage is, of course, a great disadvantage.

But one must not forget that the manner of cooking may very materially modify these comparative food values.

On the whole, pickling in brine is probably the least satisfactory of the existing methods of conserving herrings. It is, of course, the only method which appears to be practicable on the very large scale that must be adopted in the absence of effective cold-storage facilities, and in spite of the growing tendency to treat herrings in other ways—kippering, bloatering and packing in hermetic receptacles—it will probably remain the prevalent method for a very long time to come.

## The Herring as a National Food Asset.

We may consider, first of all, this Manx Summer herring fishery—about which we possess fuller information, from the food point of view, than any other. The annual quantities of herrings landed were :—

| 1914. | | Edible portion | % Proteid in edible portion. | % Fat in edible portion. |
|---|---|---|---|---|
| May ... ... ... | 677 | 57 % | 20 | 4 |
| June ... ... ... | 3,914 | 63 % | 19 | 19 |
| July ... ... ... | 9,183 | 63 % | 17 | 29 |
| Aug. ... ... ... | 5,518 | (67 %)* | 16 | 34 |
| Sept. ... ... ... | 629 | 72 % | 17 | 29 |
| Oct. ... ... ... | 15 | (57 %)* | ... | ... |
| | 19,936 | ... | ... | ... |

Converting the quantities landed into metric tons (units of 1000 kilogrammes, 1 kilo.=2·205 lbs; 1 ton = 2240 lbs.) and then " expanding " these quantities in terms of energy-values we obtain the following table. A mean chemical composition must not be taken, for the quantities landed per month are not the same. The mean monthly compositions (means of the months of 1916-1917) are " weighted " by the corresponding mean monthly catches giving the columns (3) to (4) in the next Table which professes to give the quantities of fats and proteids landed in the Isle of Man in the form of fresh herrings.

Here we have an estimate based on data that are, apparently, quite reliable. It is, of course, of little practical value, for we do not know in what particular forms the herring flesh was eaten. Much of it was eaten fresh (fried, no doubt), some was salted, and some kippered. But none of it was eaten raw, and the final results of column (5) are necessarily based on that assumption.

* There were no observations for these months and the values in brackets are interpolated.

*Manx Summer Herring Fishery.**

| Quantities Landed in Metric Tons | Edible Herring Flesh Landed. | Proximate Food Constituents Landed. | | Energy Value in millions of Calories. |
|---|---|---|---|---|
| | | Fat. | Proteid. | |
| May ... ... ... | 386 | 15 | 77 | 455 |
| June ... ... ... | 2466 | 469 | 469 | 6285 |
| July ... ... ... | 5785 | 1678 | 969 | 19578 |
| August ... ... ... | 3747 | 1274 | 600 | 14308 |
| September ... ... ... | 453 | 131 | 77 | 1534 |
| October ... ... ... | 7 | ... | ... | ... |
| (1) | (2) | (3) | (4) | (5) |

* Col. (2) is formed from the data, Ratio of edible to inedible parts, of Table p. 99; Cols. (3) and (4) are based on the mean monthly analyses of Table on page 103. The rest of the Table is obvious in its construction. The numbers of kilos. in Cols. (3) and (4) are multiplied by their appropriate energy-factors, 9·3 and 4·1, and then we get Col. 5.

The point of immediate practical importance is this—that there is really no statistical, commercial information with regard to the fishery that enables us to form any useful estimate of its dietetic value to the nation.

### The Herring Fisheries of the United Kingdom.

The White Paper* prepared by the Royal Society Food (War) Committee gives a statement of the mean annual available fish supply of the United Kingdom for the period 1909-13. It finds the quantities of all species of fresh fish landed and imported, and then subtracts the quantities of the same species exported and re-exported. The balance is the supply of fish-food available for human consumption. Deductions are made for "waste," that is, inedible components (guts, head, gills, bones, &c.) and then the fat and proteid values are calculated. The latter are expanded into calories. "The cases," say the Committee, "in which the figures are largely conjectural are few and inconsiderable."

* *Ibid.*

The available fish supply is given in Appendix Ia as 798,000 metric tons, and in Appendix Ib as 845,000 metric tons. Now from the nature of the data on which these quantities are based any reasonable approximation to the real quantities of fresh fish used as human food in the period 1909-13 seems to me to be impossible.

The cod, for instance, that were landed were whole fish (or were they gutted ?). If they were " entire " the" waste " (or inedible parts) are taken as 52 %. Then the edible part, or flesh contains, let us say, about 82 % of water and 17% of proteid.

But the cod which were exported consist very largely of dried salted flesh so that the deduction for " waste " must be very different. This dried cod flesh contains from 11 to 25 % of water and from 68 to 79 % of proteid. The quantity of " available " cod flesh given in the Report is therefore a certain quantity of fresh cod, as they are landed, *minus* another quantity of dried and salted cod exported. About one half of the first quantity is waste, but only 1/5th to 1/10th of the latter quantity can be waste. Further, one dried cod probably corresponds in energy-value to about three fresh cod.

It is assumed that all the fish are landed " entire," but is this the case ? So far as I have seen almost all sea fish are gutted aboard ship before being put away in the holds. Therefore the deduction for" waste " must be a very inaccurate adjustment. Skates and rays, for instance, were mostly landed as the " wing " parts, which are a small fraction of the weight of the entire fish. But these landings of skates and rays' " wing-parts " are then adjusted for waste. By what factor ?

Haddocks are landed fresh and gutted, and are partly sold as such. But very large quantities are also cured as Finnan haddocks and fillets, and exported mackerel are landed fresh and entire, but are exported cured. Pilchards are landed fresh and entire but are exported cured—or as fish oil.

Again, what quantities of the fresh fish landed in the period 1909-13 were ultimately condemned as human food and sent to the manure factory? Such condemnations must have been of frequent occurrence at all big ports, and the deduction to be made seems to me to be too great to be neglected.

The quantity of fish said to be "available" for human consumption during the period before the war seems, therefore, to be not even a reasonable approximation to the real quantity consumed. "It is probable," says a writer in the "Fish Trades Gazette,"* speaking evidently with exceptional knowledge of the industry, "that the home consumption of the British fish is less than 10,000,000 cwts., and possibly considerably less. There seems no doubt that much more than half the total fish landed is exported, and much less than half consumed in this country." It is evident, from the active "fish as food" campaign in England in the years before the war that there was a considerable uneaten surplus of fish. Except for the herring curing method there was no largely practised means of conservation and much of this surplus must have been destroyed. Yet if *all* the fresh fish had been consumed at home and *none at all* exported the daily ration per head of the population over 5 years of age would only have been some two or three ounces!

The amount of fish available for human consumption during the years 1909-13 must, therefore, have been less than the amount stated by the Royal Society Committee. Perhaps it ought to be taken at no more than 500,000 metric tons, instead of 800,000 metric tons.

We are prepared to find that the quantity of herring stated by the Committee to be available for human consumption is also a very questionable estimate. This quantity (162,000 metric tons in Appdx. Ia and 172,700 metric tons in Appdx. Ib) seems to have been computed as follows :—

* 20th October, 1917.

| | | |
|---|---|---|
| Landed fresh *about* | | 11,000,000 cwts. |
| Imported fresh *about* | | 1,250,000 cwts. |
| Total | | 12,250,000 cwts. |
| Exported fresh *about* | | 1,000,000 cwts. |
| Balance of fresh | = | 11,250,000 cwts. |
| *Subtract* pickled herrings | | 8,000,000 cwts. |
| Balance of fresh | = | 3,250,000 cwts. |

(Where the quantites are, of course, all " rounded " ones.)

Now the propriety of subtracting a quantity of herrings exported pickled in strong brine, from another quantity landed fresh is obviously doubtful. The deductions for " waste " are different, and the composition of the edible parts is also different. What the difference may be one cannot say, but it ought to be known before the " balance available " is expanded into calories and the latter shared out among the population.

Further it is *very* doubtful if the 3,250,000 cwts. that results from this computation was eaten fresh in Great Britain. " Less than one quarter of the herrings brought ashore enter into home consumption," say the Board of Agriculture and Fisheries ; while " probably not more than 14 or 15 % of all the herrings landed in Scotland are consumed in this country," says the writer quoted in the " Fish Trades Gazette."* Taking 20 % of all the landings of herrings as a reasonable approxi mation to the quantity consumed, we get about 110,000 metric tons instead of the 160,000 metric tons given by the Royal Society Committee.

### The Analytical Data of the Composition of Fish Flesh.

The quantity of fish flesh available for human food having been obtained (or not), the next step is to convert this quantity into proteid and fat constituent quantities. Analyses of all

* *Ibid.*

the species of fish landed are therefore necessary. The Royal Society Food (War) Committee have adopted the series of analyses of American fishes made by Atwater and Woods,* " modified in accordance with the special characteristics of the British supply." Now these American analyses are obviously very carefully made and may be taken as most reliable, but after all they are analyses of American species of fishes. Some of the species are the same (Linnean) ones in both English and American seas, cod, haddock, whiting, herring (for instances), but it by no means follows that the composition of the flesh is the same. Soles and plaice occur in the Royal Society Committee's list, but these do not occur in Atwater's analyses, and the North Sea sole and plaice are not found in American waters. Eels, hake, skates and rays are different species in American and European waters. Salmon may be the same or different. The Shell-fish (Molluscs and Crustacea) are different species. The " other kinds " are mostly different, but they are not distinguished, zoologically or nutritively, in the Report. Even if the species were the same, one must insist, the chemical composition cannot be taken as the same unless we know that it is so. Estimates of the energy, or food-values of British-caught fishes cannot therefore be regarded as reasonably approximate if they are based on analyses of American caught fishes. Why were these American analyses taken ? There are many others which apply to European species.†

Here we are only concerned with the herring. Atwater's analyses dealt with 4 fish only, and the source of these is not stated, nor their conditions, nor sexual phases. The edible

* " Chemical Composition of American Food Materials," *Bulletin No.* 28 (revised edition) *U.S.A. Department of Agriculture*, 1906. The original paper is " The Chemical Composition and Nutritive Value of Food Fishes and Aquatic Invertebrates," W. O. Atwater, *U.S.A. Commission of Fish and Fisheries, Commissioners' Report*, 1888 (1892), pp. 679-868, Plates LXXXI-LXXXIX.

† König, Dr. J., " Chemie der menschlichen Nahrungs- und Genussmittel." I. Band. Berlin, 1903, pp. 43-70, 1456-1458. The work is a compilation of all available analyses of fish and shell-fish.

parts of these fishes contained 72·5 % of water, 19·5 % of protein, and 7·1 % of fat. On the whole, this analysis corresponds well with that of Manx Summer herring at about the beginning and end of the fishing season, when the fish are in relatively poor condition, but the American fishes would be relatively of low food value when compared with the Summer-caught Manx fish in best condition; probably also with fresh Summer-caught herrings; and also with some Summer-caught East Coast fish. Then we have Milroy's Analyses of East and West Coast Summer and Winter-caught herrings,* where the composition of the fish is considered most carefully in respect to their reproductive phases. Here too, we find very marked variations in the energy-values according to the season of capture.

Obviously a "flat" rate of composition cannot be computed and used to convert quantities landed into food values. The only reasonably accurate method seems to me to be that suggested in relation to the Manx herring fisheries: the composition in each month, and main fishing region, must be found and weighted by the relative quantities landed in respect to those months and regions.

The whole relevancy of this discussion is this: all at once the question of the potential food resources of the United Kingdom became one of some significance. Now no public department, nor other local authority, was so equipped as to be able to provide statistical and scientific data such as would enable anyone to supply the information required. For some years back (since about 1908) statistics of fish landed have been greatly improved, and the information is probably adequate for the purpose for which it was designed—the study of the fluctuations of the fishing industry in relation to the regions exploited. But, as we have seen, this information

* "The Food Value of the Herring," *Ann. Repts. Fishery Board for Scotland*, Pt. III; Rept. for 1905, pp. 83-107 (1906); Rept. for 1906, pp. 197-208 (1907).

does not help us much when we attempt to deduce the actual value of the fisheries as sources of food. So many are the sources of error and so great is our ignorance of the nutritive value of the products as they enter into commerce, that any estimate, such as that attempted by the Royal Society Food (War) Committee, must be of theoretical rather than of practical administrative interest. Even the theoretical interest of the estimate resides in the methods employed rather than in the results.

## Some Physiological Questions.

The locus of the fat.

First of all something must be said about the mode of occurrence of fat in the tissues of the herring. Various attempts were made to obtain good sections showing the fat *in situ* in the flesh, but all were unsuccessful. The fat itself is liquid at ordinary temperatures and runs away when thin slices of the flesh are cut out for fixation: on the other hand large blocks of tissue fix imperfectly. In most processes of rapid fixation considerable contraction of the flesh occurs, and the fat is thus squeezed out, and only by employing formaline was this avoided. Various methods were employed in order to render the fat solid and insoluble in the reagents utilised for staining, but no success was obtained. Sections were cut from frozen tissues and from tissues embedded in celloidin and hardened gelatine, but whenever the staining and mounting was attempted the liquid oil oozed out from the connective tissue cells and spread over the section. Neither did teased preparations stained with Sudan III give good results since the oil spread out, bathing the muscle fibres and making a general mess. In the end ordinary paraffin sections were cut from formalin-fixed tissues and stained by Mallory's method. It was possible then to see, in a general kind of way, *where the fat had been.*

The Text-fig. on p. 119 represents such sections made

Fig. 1. Fig. 2.

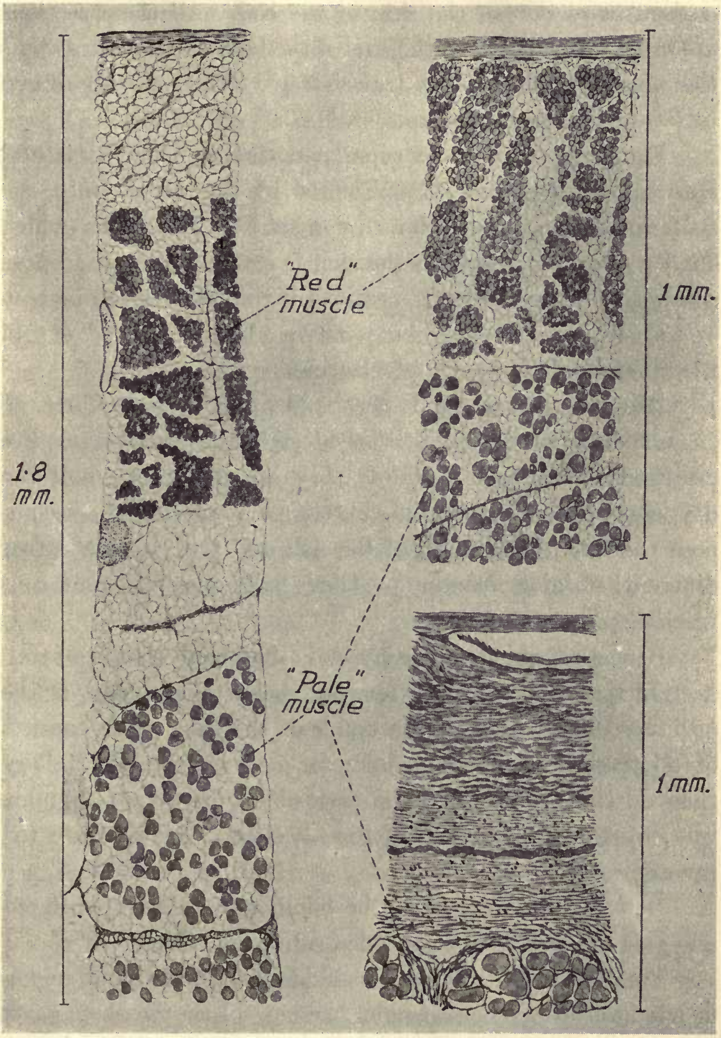



Fig. 3.

Fig. 1. Transverse section of Summer-caught Herring.
Fig. 2. do. do. Winter-caught Herring.
Fig. 3. do. do. Cod.

from Summer-and Winter-caught herrings, and also (for comparison) a section of the skin of the cod. All three sections are made transversely to the axis of the body of the fish, so that the muscle fibres are cut transversely. They are all drawn to (approximately) the same scale.

Fig. 1 represents the superficial tissues near the lateral line region. The skin is represented by the dermis only, the epidermis having mostly been removed with the scales (which cut very badly). Beneath the skin is a thick layer of adipose connective tissue—only the outlines of the fat-cells can be seen in the section, the oil-globules having been dissolved out in the process of fixation and clearing.

Beneath this, again, is the band of red muscle fibres, so characteristic of Clupeoid fishes in general. These fibres are arranged in compact bundles; they are about one half the diameter of the fibres making up the pale muscles which compose the bulk of the flesh of the fish, and they have a rather different staining reaction. They have also different contractile properties.*

Beneath this is another layer of "blubber," that is, of connective tissue loaded with fat, and below this, again, is the ordinary musculature of the trunk of the fish. This consists of relatively thick fibres, staining far more lightly with Mallory than do the red fibres. It is divided up, in a very complex way, by the dissepiments of fibrous tissues that separate the myotomes.

Between the fibres and the bundles of fibres, of both red and pale muscles, is also fat-laden connective tissue.

Fig. 2 represents a section made through the same region in the flesh of a Winter-caught herring. Just the same parts are indicated except that the layers of "blubber" are absent, and there is, on the whole, less adipose tissue between the bundles of pale and red muscles fibres.

* *See* Stirling, *Ann. Rept. Fishery Board for Scotland.* IV, p. 166 (1886).

Fig. 3 represents a section taken from the "shoulder" region of a large cod: it, too, is made in the transverse plane. The epidermis has been lost by rubbing in the course of handling the fish in commerce, but a scale is shown. The scales in this region are usually buried in the dermis in pockets. The dermis is mostly a very thick layer of coarse fibrous tissue, divided up obscurely into blocks. Beneath it is a layer of much finer connective tissue, differentiated into several sub-layers, and beneath this again is the musculature (the fibres being rather coarser than those of the herring). These various regions or layers of "skin" and superficial tissues need not be described more minutely (they are really very complex and variable in different fishes). What the figures are intended to show is the general situation of the oil which is present in the "flesh" of the herring; the contrast between Summer and Winter herrings; and that between fat-rich fishes, like the Clupeoids, and fat-poor fishes, like the Gadoids.

Fat also occurs in the massive form, in the herring, as deposits in the peritoneum and mesenteries, and sometimes it is very abundant there, so that dissection becomes a "messy" task on account of the liquid nature of the fat. It occurs, of course, in the liver also, but the latter organ is not very large in Clupeoid fishes. Both liver fat and massive peritoneal fat may differ chemically from that which may be expressed from the flesh—at least such seems to be indicated by mere examination: little has, of course, been done to distinguish the differences.

In fat-poor fishes, such as the Gadoids, the liver is the great store place. Both in these fishes, and also in Skates and Rays, the liver undergoes very marked seasonal changes, becoming both larger and richer in oil in the warm months. In these fishes the condition of the liver is always noted by fishermen (it is sometimes eaten) and regarded as indicative of the dietetic value of the flesh. More than half the weight of cod liver may

consist of oil, and in some species of Gadoids the amount of oil may be so large that the liver will easily burn without much spluttering.

The general metabolism, in so far as the storage of surplus fat is concerned, therefore differs notably in the Clupeoid and Gadoid fishes. The flesh of the former is rich in fat, that of the latter is poor in fat. Upon this difference depends the differences in methods of curing and conservation. *Why* this difference in fat-metabolism should exist, we find it hard to explain. Both groups of fishes have the same general habits (except that the Gadoids are more demersal than Clupeoids) ; they frequent the same waters and live, in general, on the same food animals—Crustacea.

The nature of the fat.

Opportunity for more than a very superficial examination of the chemical and physical nature of the fat has not yet been afforded. There are probably seasonal differences in composition, and, of course, what one calls " fat " or " oil " is certainly a mixture. Expressed or extracted in such circumstances as to avoid oxidation, it soon separates into constituents of different melting point and refractive index. Some part of it is very easily oxidised at the temperature of boiling water. Extracted in an atmosphere of H or $CO_2$ it is pale yellow in colour, but, heated to 100° C for a few minutes, it darkens greatly. Yet the oxidation has, for its main effect, the production of a small trace of this pigment, for the weight is not greatly increased.

The fats of the food-animals eaten by both herring and cod—that is, of Crabs and other Crustacea (Cod), and Copepods and other micro-crustacea (Herring)—are apparently different in chemical composition from that of the fish : they are generally coloured, for instance. So also the fat of the food of the Copepods (that of Diatoms and Peridinians and Algae) is also

different in all probability. But it would, perhaps, be difficult to account for the rather rich fat-contents of Copepods merely by the fat contained in Diatoms and Algae, and we seem to be compelled to postulate a synthesis of fat from either the carbohydrates or proteids of the latter organisms.

The seasonal metabolic phases.

In the case of the herring, that is, in the case of the individuals of a differential race, or "elementary species" of herring, the phases are to be arranged into two categories (1) those which make up the annual reproductive cycle, and (2) those which are to be related particularly to the annual wave of sea-temperature. In reproduction the gonads (ovaries or testes, that is, "hard and soft roes") gradually enlarge. First there is rapid proliferation from the germinal epithelium, then growth in size of the eggs, or multiplication with diminution in size of sperm mother-cells. The ova remain opaque for a considerable time, then acquire their fat globules, and absorb water, becoming glassy clear. Then they dehisce from the germinal epithelium, lie freely in the cavity of the ovarian sac, and are finally extruded. The ovary then shrinks up and becomes very much smaller than it was before spawning.

Corresponding changes occur in the testes. Both organs are about the same size, and have very much the same ratio of weight to total body weight. In most other fishes the mature testes are smaller than the mature ovaries, and in fishes like the sole very considerably smaller.

In the case of the herring (but in that of no other British marine food fish) spawning may occur at any time during the year. Most British caught herrings spawn during the Summer and Autumn months, but a large fraction spawn during the late Autumn and early Winter, while those caught off the north west coasts of Scotland spawn in the early months of the year. There is little spawning during the late Winter and Spring

months, that is, immediately after the minimum of sea temperature.

So far as we know each local race, or elementary species is characterised by the (approximately) constant habit of spawning at the same time of year. Thus we have at least two local races in the Irish Sea, the Summer-spawning (September) Manx herrings, and the Winter-spawning (November-December) Welsh fish. The former are fat-rich and the latter are (relatively) fat-poor. Further there are morphological differences indicated when precise measurements of certain characters are made.* Looking at these differences from the point of view of the theory of sampling, the distinction between the two races appears very clearly. Both may be regarded as belonging to the same population, or local race: if so, the differences in value of the diagnostic morphological characters ought to be such as to be capable of explanation on the assumption that they are due to errors of random sampling. Application of the theory of error shows that the probability that such is the case is very small and we are forced to conclude that the two races are differentiated morphologically as well as physiologically.

Concomitantly with the metabolic changes in the gonads there are changes in the chemical composition of the flesh, or rather changes in the ratio of fatty to truly muscular tissue. In all races of herrings the maturation of the ovaries and testes is accompanied by an increase of fat in the " flesh," that is by the loading of the subdermal and intermuscular connective tissue with fat. For some time before the fish spawns (but after the major part of increase in mass of the gonads has taken place) the fat-contents decrease, and after spawning this decrease becomes very rapid. Between the time of spawning and the time at which maturation of the gonads begins again, the fat-contents of the " flesh " is at its minimum value. This

* Riddell, *Rept. Lancashire Sea-Fish. Laby. for* 1915, p. 32. *P*, the probability, varies between $<0{\cdot}000001$ and $0{\cdot}144$ for different characters.

series of changes is well shown in the Tables on pp. 93 and 94. In 1914 the fishery began in June, when the herring flesh contained about 5 % of fat. The maximum percentage of fat (35 %) was observed about the middle of June. Spawning began about the end of August when the percentage of fat fell to about 17 %. By the end of September the herrings were "spent," and the percentage of fat in the flesh had then decreased to about 9 %. With the completion of spawning the shoals disperse and the fishery comes to an end.

The same series of changes is clearly to be seen in the Tables of p. 94, which relate to the fisheries of 1916 and 1917. At the beginning of the season the percentage of fat in the flesh was about 3 to 4 % and then rose to a maximum of about 33 % (in August of 1916), and to about 42% (at the middle of July of 1917). In both years the herrings became "full" in September (maturation of ovaries and testes had been completed) and then the fat-contents began to decrease. In neither year were actually spawned fish sampled.

The changes in Proteid.

Not only does the percentage of fat in the fresh, wet flesh vary but that of "proteid" (or nitrogen $\times$ 6·25) also varies. This is clearly seen in the Tables of p. 103, which give the monthly means for 1916 and 1917. The proteid-percentage is relatively high at the beginning of the season, then decreases and becomes minimal at the time of the maximum of fat-contents (or of maturation of the gonads), and then rises again towards the time of spawning.

But this is the percentage of proteid calculated on the wet weight of flesh, that is, on the sum of the weights of water + fat + proteid + ash, and it is therefore a rather complex function. In actual practice the wet flesh was first dried in the steam oven, then extracted to remove the fat, then finely

powdered and again dried. The residues were then examined for proteid, giving the results :—

*Percentages of* ($N \times 6{\cdot}25$) *in various herrings: means.*

| Month and Source. | 1916. | 1917. | 1918. |
|---|---|---|---|
| Manx, May ... ... ... ... ... | 76·4 | 93·8 | ... |
| ,, June ... ... ... ... ... | 78·6 | 82·5 | ... |
| ,, July ... ... ... ... ... | 78·1 | 84·0 | ... |
| ,, August ... ... ... ... | 78·9 | 83·5 | ... |
| ,, September ... ... ... ... | 80·5 | 81·2 | ... |
| Means ... ... ... | 78·5 | 85·0 | ... |
| Welsh, November, Mean of 3 samples ... | ... | 90·6 | |
| Shop, November ... ... ... ... | ... | 90·5 | ... |
| ,, February ... ... ... ... | ... | ... | 91·9 |
| Mean ... ... ... | ... | 91·4 | |

Now it is difficult to see that the variations from month to month in the case of the Manx Summer herrings are of real significance. Whatever the analytical error in the estimation of $N$ may be it is multiplied by 6·25, and so we must regard the errors of the percentages of " proteid " in these residues as rather high, say 0·5 to 1 %. But we may perhaps distinguish safely between (1) Manx Summer herrings of 1916, (2) Manx Summer herrings of 1917, (3) Winter herrings. Here the differences in the percentage of $N \times 6{\cdot}25$ lie well outside the analytical errors.

## The Proteid Factor 6·25.

Thus the percentage of ($N \times 6{\cdot}25$) in the various water-free, oil-free residues varies between about 78 and 92, while the percentage of non-volatile matter is never more than about 3. A balance of about 19 to 5 % is thus left unaccounted for by the analyses, and it is always possible that this balance may be represented by reducing substances (' carbohydrates ").

Such are, indeed, described by Miss Williams,* but the results obviously require confirmation in view of the general statements that carbohydrates are absent, or are present in negligible quantities only, in fish flesh.

It is also probable that the apparent deficiency in the analyses is to be traced to the employment of the particular factor, 6·25, by which the nitrogen actually found analytically is assumed to be converted into proteid. There has been much discussion as to the value of the factor which is appropriate to fish proteids, and there is a good resumé in Atwater's paper† already noticed here. This investigator gives a list of analyses in which the propriety of using the factor 6·25 is doubtful, and he discusses whether or not the percentage of proteid present in fish flesh ought to be estimated by difference, or actually by determination of the nitrogen and multiplication of the latter by 6·25. It seems to me that the method of estimating proteid by difference—that is assuming that whatever is not water, nor ether-extract, nor non-volatile mineral matter —is " proteid "—is good enough for dietetic purposes, but it is obvious, from a consideration of Atwater's results, that it is not accurate enough for metabolic studies.

Thus some of the percentages of water, fat-extract, proteid (that is, $N \times 6{\cdot}25$) and mineral matter in the Manx Summer herrings is only about 98 %. Winter herrings give more satisfactory results, the sum of the above percentages being 99·7 %. On the other hand analyses of red herrings gave an error in excess, the water, fat, proteid and ash adding up to 102·5 %. It was thought that the analysis of " proteid " was inaccurate here, and the estimation was repeated with the result that 26·52 % of ($N \times 6{\cdot}25$) (the first analysis), 26·45 and 26·52 were obtained for the percentages of ($N \times 6{\cdot}25$) in the dried residue. We have, therefore, a total range of about 2½ % above and below

* *Loc. cit.* Reducing substances reckoned as glucose vary between about 1·5 and 9·5 of the net weight of cooked flesh.

† *Loc. cit.*

100 % as the deviation from the theoretical sum of the constituents present.

Most probably this deviation is to be accounted for by the presence, in variable quantity, at different seasons, or in herrings variously cured, of some substance in which the nitrogen is present to a greater or lesser extent than 16 %. What this substance may be has still to be determined, and the investigation obviously has much theoretical importance.

The Temperature Factor.

Inspection of the Tables on pp. 93-4 will show that the percentage of fat in herring flesh varies in a regular manner. It is least (for the Manx fish) in May (when the sea-temperature is rising from its minimum in March); it increases to its maximum in August (when the sea-temperature is also maximal) and it then decreases as the sea-temperature begins to fall towards its next minimum. The two variables, fat-percentage and sea-temperature, can be plotted on the same time-scale of abscissae, making the two ranges of ordinates cover the same part of the vertical scale, and it will then be seen that there is a certain degree of correspondence in the curves—the variables are correlated.

The fat-percentage is, of course, a function of several independent variables, sea-temperature being only one of the latter. The sexual cycle is a function such that the fat-contents of the "flesh" accumulate, while the ovaries or testes are growing in mass, and also such that the percentage of fat diminishes rapidly just before and after the act of spawning. The large increase of oil in the flesh may be regarded, from one point of view, as an excretion. While the gonads are growing in mass the proteid percentage in the flesh is decreasing, and it may be suggested that proteid is being transferred from muscles to gonads, becoming rearranged, with the elimination of fatty acid residues, and that the latter accumulate in the flesh. This

possible change ought, however, to be worked out quantitatively before it can be regarded as more than possible.

Temperature alone must be a factor, since during the corresponding series of changes in Winter-spawning herrings fat accumulates but not to the same extent as in the Summer herrings, though the ratio of mass of gonads to total body mass is much the same in both categories of fish. In other words the temperature function is just that expressed in van 't Hoff's law, the rate of chemical change is a function of the temperature. There is greater assimilation, and accumulation of reserve material, in seasons of high sea-temperature than when the latter is relatively low.

In fact the sexual series of changes can be left out of consideration in selected cases. Plaice of less than about 30 cms. in total length are immature, and the ratio of mass of gonads to mass of body does not change throughout the year. But the "condition" of the fish, that is, its weight per unit of length varies regularly with the temperature. The expression $w = k\frac{l^3}{100}$ represents this variation in condition with considerable accuracy, $w$ being the weight of the fish in grammes and $l$ its length in centimetres. The coefficient $k$ varies between about 0·8 and 1·2, being least at the season of minimal sea-temperature and being maximal when the sea-temperature is also maximal. A somewhat similar relation holds for the herrings investigated here. Weight per unit of length, and sea-temperature, are therefore variables which are directly correlated. The variation in the coefficient $k$, in the case of the plaice and herrings, means that new tissue is being formed and accumulated during the season of rising sea-temperature, and that this tissue is being destroyed during the season of falling sea-temperature. The tissue that is formed in the plaice seems really to be muscular substance, but in the herrings it is adipose connective tissue.

Concomitantly with this variation in mass of flesh per unit length (in the plaice) there appears to be a decrease of water in the flesh, and (in the herring) a decrease of water, an increase in oil, and a slight decrease in proteid.

The temperature factor an integrative one.

The sea-temperatures considered here are those recorded daily at Carnarvon Bay Light Vessel, which is placed at a station not very far from the herring fishery region, and is such that the sea-temperature is not affected to any considerable extent by "accidental" factors like tides, or the influence of the land: these data represent very well the periodic changes of temperature in the sea. The periodicity is, of course, mainly annual, but there are significant differences in the amplitude of this annual wave from year to year—another period of several years, in fact, being superposed on the annual one. The maximum of sea-temperature for the period 1907-1916 occurred at the end of August and was about 14·6°C. The minimum occurred about the middle of March and was 7·6° C.

The effect of sea-temperature upon the metabolism of the herring is, however, a cumulative one, that is, we must correlate the variations in fat-contents and time of spawning with the *total* quantity of heat received during the period of the maturation of the gonads. In other words, we must consider, not the slope of the sea-temperature curve but rather the integral of the curve between the limits represented by the beginning of the fishing season and the time of spawning. The temperature function must be integrated. Now the function itself is a rather complex harmonic one, and the technical integration is difficult, but we can approximate to its value by simply summing the 10-daily means of sea-temperature: we find $\Sigma_{t_2}^{t_1}\theta$, where $t_1$ and $t_2$ are respectively, the beginning of March and the end of September, and $\theta$ is the mean sea-temperature

for each 10-daily period in degrees Centigrade. Making these calculations we find :—

Temperature-integral for 1907-1916, Mar. to Sept. = 236·3
Temperature-integral for 1914, Mar. to Sept. = 266·2
Temperature-integral for 1916, Mar. to Sept. = 243·9

Considering these results we see at once that the differences in time of spawning and percentage of fat between 1914 and 1916 are to be correlated with the integrative temperature factor. Spawning occurred relatively early (in August) in 1914 because of the relatively great cumulative heat effect, and relatively late in 1916 for the opposite reason.

# THE PLAICE FISHERY OF 1892-1917.

By James Johnstone, D.Sc.

Some interesting results have been obtained during the examination and tabulation of the statistics of experimental trawling operations carried out during the past 25 years. A report on these results has been prepared, and it is hoped that it may be possible to publish this at some future time. Meanwhile, allusion may be made to some points of special interest.

## The Plaice Fishery of the Mersey Estuary.

Experimental hauls with fish-trawl nets of various meshes and dimensions, and also with shrimp-trawl nets, have been made regularly since 1892 by Captain Eccles. These trawling operations were carried on in the Mersey Channels and outside the Banks. As a rule, they have been made under nearly uniform conditions, and all the circumstances as to weather, etc., are recorded. Since about 1908 all the plaice caught have been individually measured in centimetres—work requiring considerable patience and accuracy.

In considering these figures, one sorts them out into average catches of plaice, etc., per haul per month—or into average catches per hour's fishing per month or per annum. The latter is the most obvious way of dealing with the figures, and we see at once that there are quite remarkable variations. Nevertheless, to take the numbers of plaice caught per hour's fishing, per month, is not a very satisfactory method, for there are usually not very many hauls per month, nor even per year. And in comparing year with year there is the difficulty that some months are well represented in some years but not in

others. Since the abundance and average sizes of the plaice caught vary greatly from month to month, this unequal fishing disturbs the averages. Also one very large catch of plaice among a number of very ordinary catches raises the average unduly and gives us a distorted idea of the variation.

So, instead of average catches per hour's fishing, we try to find some other form of average. I have arranged the catches made by the fish-trawl and shrimp-trawl in groups of 3 years, which overlap—thus, 1892 to 1894, 1893 to 1895, 1894 to 1896, etc., and then the numbers of plaice caught per haul are arranged in groups of 0 to 50 fish, 51 to 100, 101 to 150, and so on. Thus we consider *all* the separate hauls made during each of the overlapping groups of three years, as follows:—

| | | | | | |
|---|---|---|---|---|---|
| *Nos. of plaice caught per haul* ... | 0-50 | 51-100 | 101-150 | 151-200, | etc. |
| *Nos. of times each of these results was obtained* ...... | 24 | 29 | 5 | 7 | etc. |

We see that 24 of the hauls made during the years 1912-14, for instance, contained from 0 to 50 plaice, 29 contained from 51 to 100, 5 contained from 101 to 150, and so on.

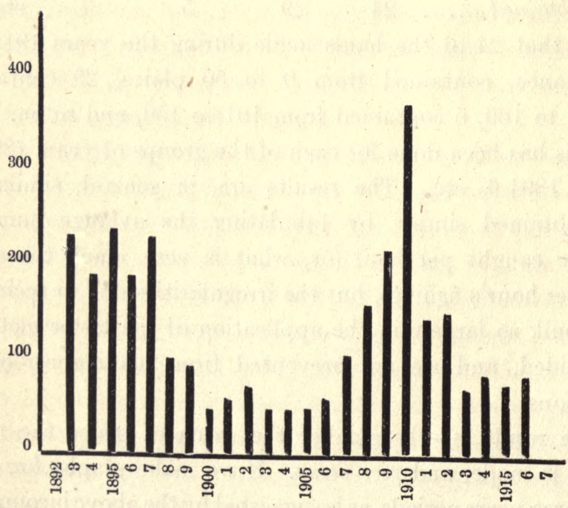
This has been done for each of the groups of years 1892-4, 1893-5, 1894-6, etc. The results are, in general, similar to those obtained simply by tabulating the average numbers of plaice caught per haul (or, what is very much the same thing, per hour's fishing), but the irregularities due to accident, which bulk so largely in the application of the latter method, are avoided, and we are prevented from making erroneous conclusions.

The result is—the smaller the catch of plaice the more often it is made, and *vice versa.* If we make graphs for each of the three-years periods, as is suggested by the above incomplete table, we get *J*-shaped curves, the tail of the *J* being drawn

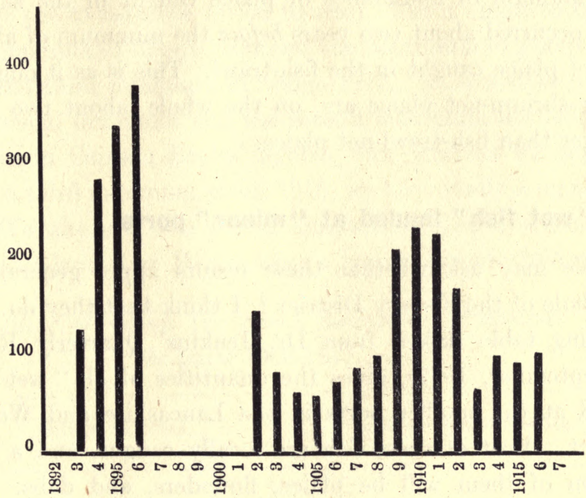
out into a nearly horizontal line. An extension of this method of making the curves enables us to arrive at the following results (for the period 1912-14):—

> There were 85 hauls in all, and in these either no plaice or some plaice were caught;
>
> In 61 out of the 85 hauls more than 50 plaice were caught;
>
> In 32 hauls out of 85 more than 100 plaice were caught;
>
> In 6 hauls out of 85 more than 500 plaice were caught;
>
> In 2 hauls out of 85 more than 1,000 plaice were caught.

Then we can easily find out, from the same curves, what was the "shortest half-range" of the plaice caught in each period. Thus we can say whether one half of all the hauls gave 0 to 50 plaice, 0 to 60, 0 to 100, 0 to 150, and so on. These half-ranges make a kind of averages, and these averages are tabulated in the following diagrams:—




Variation in the numbers of plaice caught in the shrimp trawl.




Variation in the numbers of plaice caught in the fish-trawl.

(Data for the years 1898-9-10 are missing).

We see at once from these diagrams that there has been a very regular variation in the abundance of plaice, of one to three years old, on the Mersey fishing grounds. Some time about 1890-2 there was a minimum of abundance, and there was another minimum about 1905. There was a maximum about 1895, and another maximum about 1910. Just about the present time there is another minimum. That is to say, there have been two complete periods of variation in the abundance of plaice on the Mersey fishing grounds between about 1892 and about 1915.*

The variation seems to be very much the same for the plaice caught in fish and shrimp trawl nets, but if we take single years instead of groups of three years, and adopt certain precautions to get rid of accidental variations, we find that

* Until we have other two or three years' records the precise date of the latter minimum must be rather uncertain.

the minimum of abundance of plaice caught in the shrimp-trawl occurred about two years *before* the minimum of abundance of plaice caught in the fish-trawl. This is as it ought to be for shrimp-net plaice are, on the whole, about two years younger than fish-trawl-net plaice.

### The "wet fish" landed at "minor" ports.

We may ask whether these results apply generally to the whole of the Fishery District ? I think that they do. The following table (taken from Dr. Jenkins' Quarterly Report for September, 1917), gives the quantities of all "wet fish" landed at the smaller ports in the Lancashire and Western District. Most of these fish are locally caught, and a large fraction of them will be plaice, flounders, and dabs. The figures are "smoothed" by taking the averages of three-yearly groups, as we did above. The figures for the last year (1917) are incomplete, the last quarter being missing.

*Quantities (in cwts.) of Wet Fish landed at minor ports in the Lancashire and Western Fishery District.*

| Groups of years. | Average quantities landed. |
|---|---|
| 1906-8 | (Minimum) 26,342 |
| 1907-9 | 28,748 |
| 1908-10 | 31,371 |
| 1909-11 | (Maximum) 36,518 |
| 1910-12 | 36,120 |
| 1911-13 | 34,511 |
| 1912-14 | 29,968 |
| 1913-15 | 32,929 |
| 1914-16 | 37,333 |
| 1915-17 | 37,109 |

Now, this period, 1906-1917, covers only a part of that included in Captain Eccles' statistics (for the collection of fishery returns was very faulty up to the year 1906, and it

is best not to take the earlier figures). But it ought to include the minimum of about 1906 and the maximum of about 1910, and the third minimum of about 1915. As a matter of fact, the second minimum and the second maximum are indicated, just as in Captain Eccles' figures, but, whereas we ought to have a third minimum about 1915, we have really a maximum.

We take now, as a further comparison, the actual quantities of plaice landed at Morecambe, a typical inshore fishing port.

*Quantities of plaice (in cwts.) landed at Morecambe during the years* 1908-1917.

| Groups of years | Average quantities landed. |
|---|---|
| 1908-10 | 1,119 |
| 1909-11 | (maximum) 1,286 |
| 1910-12 | 1,074 |
| 1911-13 | 863 |
| 1912-14 | 679 |
| 1913-15 | 969 |
| 1914-16 | 1,823 |
| 1915-17 | 2,987 |

Here, the quantities landed are " smoothed," as before, by taking the averages of groups of three overlapping years. Again we see that the quantities are rising from a minimum (which was before the date of commencement of the Table), that there was a maximum in 1910, and that there ought (in comparison with the diagrams of pp. 134 and 135) to be a minimum in 1915, whereas the quantities landed in that year tend to a maximum.

Thus the Tables of all wet fish and of plaice landed at the fishing ports show the same series of changes (so far as the figures go) as do the statistics of plaice caught on the Mersey trawling grounds. But there is this difference: the latter figures indicate that there was a minimum of abundance of plaice about the years 1915 or 1916, whereas the statistics

of fish actually landed show that there was a tendency to a maximum of abundance in these years.

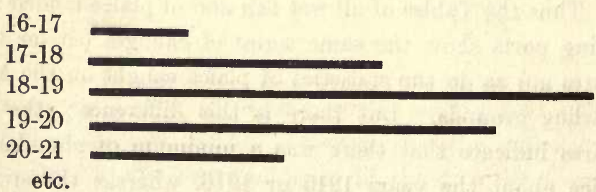
So we must reconsider Captain Eccles' statistics enquiring, first of all, whether or not there have been

**Changes during the period of war?**

No doubt at all there must have been a decrease in the amount of fishing going on in the offshore waters during the years 1915-7: has this affected the productivity of the inshore grounds? It is very difficult to say whether or not this has been the case. At first, we might think that if there have been fewer fish (say plaice) caught offshore there ought to have been more and larger fish caught inshore. Now, the diagrams on pp. 134 and 135 seem to show that there has been an actual decrease in the numbers of plaice caught on the Mersey (inshore) grounds during the period 1910-1917. The minimum of abundance may have been in 1915, 1916, or 1917: it is difficult to say until we have several years more statistics. But there has been no certain increase—that we may be pretty sure about, nor has there been an increase in the size of the plaice caught during the years of war.

**Prevalent sizes of plaice caught on the Mersey grounds.**

We can best study the variations in length of the plaice landed by taking "shortest half-ranges." We make a curve of the sizes of the fish caught for any month, or year, or group of years, and then find what are the sizes of the plaice caught most frequently. Thus let the following diagram represent a catch:—




Centimetres of length.

The lengths of the horizontal columns represent the variations in the percentages of the plaice caught of 16 to 17, 17 to 18, 18 to 19 centimetres in length, and so on. We see that the majority of the fish caught lie between about 17 to 20 centimetres in length. It is easy to find what is the shortest range of lengths (say 17 to 21) which includes just one half of all the fish caught. This is the shortest half-range, and it is the best expression for the average size of the fish caught.

Calculating these half-ranges for various periods, we get the following results :—

| Period. | Shortest half-range. | Over 20 cms. long. |
|---|---|---|
| | | % |
| 1908-1913 | 19-23 | 72 |
| 1914 | 17-22 | 68 |
| 1915 | 17-22 | 54 |
| 1916 | 20-25 | 82 |
| 1917 | 17-21 | 49 |

Now, 1916 was an exceptional year, and the numbers of plaice caught by Captain Eccles in the months September and October (which are those dealt with) were rather small. Considering the other years we see at once, not only from the half-ranges, but also from the percentages of all the plaice that were over 20 centimetres in length, that the average sizes ran smaller and smaller during the period 1908-1917. It must be admitted that this result was unexpected. It will be very interesting, when some years have elapsed, to consider these variations, year by year, throughout the whole period from 1908 onwards. In the meantime it would appear that not only does the actual abundance of plaice undergo variations from year to year, but also that the average sizes of the fish undergo concomitant variations.

Certainly, during the period of war conditions, the quantities of plaice landed by inshore fishing vessels have

increased. But that indicates nothing more than this—that fishing has become much more profitable since 1914; that there is an increasing demand, and therefore better prices, and that fishermen have found it pays better to abandon other methods of working in favour of these lucrative ones, or else to trawl more often than they did in pre-war times.

---

These (preliminary) observations show that there has been a very marked natural periodicity in the productivity of the plaice fisheries during the term of years 1892-1917. Maximum succeeds minimum, and minimum succeeds maximum with regularity, so far as the data go. It will be interesting to find whether this periodicity is maintained in future years, and it is very important that these experimental trawlings in the Mersey Estuary should be continued by the same methods, and with the same care and intelligence as that displayed by Captain Eccles.

As for the artificial change in conditions resulting from the circumstances of war, this has not affected, in the least, the natural periodicity noted here—at least, there is no evidence, so far, that it has done so.

March 20. 1919.